# ASSESSMENT OF

# ELECTRONIC WASTE MANAGEMENT IN HARARE,

# ZIMBABWE

by

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## DEDICATION

To my late father, Leonard, Sons Tinashe Prince, Unathi Eric and Anotida Leonard Ian. Only daughter Tinevimbo Blessing, wife Chipo, mother Agnes and the Leo family.

## DECLARATION

I, **Mandevere Benjamin,** sincerely declare that this thesis, entitled*:* ***Assessment of Electronic Waste Management in Harare, Zimbabwe*** that I am submitting for the degree of **Doctor of Philosophy** on the subject: Environmental Science at the University of South Africa, is my own work. It has previously not been submitted by me for a degree at this, or any other institution.

I declare that the thesis does not contain any work presented by other persons, whether written, pictorial, graphical, and statistical or any other information without acknowledging the source. Where words from a written source have been used, the words have been paraphrased and referenced. In those instances where exact words from a source have been used verbatim, such wording has been placed inside quotation marks and systematically referenced.

I further declare that I have not copied and pasted any information from the internet, without specifically acknowledging the sources and inserting the appropriate references to them in the reference section of the thesis. Similarly, I declare that during my doctoral research, I adhered to the Research Ethics Policy of the University of South Africa. In this vein, I first received ethics approval for my study, prior to the commencement of data gathering and have not acted outside the approval conditions.

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SIGNATURE DATE

Mr Benjamin Mandevere

# ABSTRACT

*E-waste entails electronic equipment and or part thereof, which is or considered obsolete resulting in it being discarded with no intention for reuse. The advent of the Fourth Industrial Revolution (4IR) has seen a rapid increase in electronic waste across the globe. However, while universally, volumes of e-waste are exponentially increasing, the ability of most developing cities to manage such waste has not. In Harare Zimbabwe, e-waste has become an additional waste management challenge as there are few e-waste recycling companies, and more informal "recyclers". More often than not, these recyclers are ignorantly vulnerable to e-waste related diseases emanating from e-waste related pollution. It is in the light of this, that this study aimed to assess electronic waste management in Harare, Zimbabwe with the primary objective of developing a feasible e-waste management model for the city. To this end, the research was a mixed-methods study of interviews, structured questionnaires, observations and laboratory experiments. Primary data revealed that e-waste is being dumped at both the city's official dumpsites and also on roadside dumps across residential areas, mostly high and medium density areas. While laboratory analyses exposed the presence of e-waste related heavy metals on selected dumpsites as well as at other non-dumpsite areas in Harare. Conversely, a review of secondary data testified that Zimbabwe's current environmental legislation is bereft to non-specific about e-waste. With no legislative framework nor e-waste management services available therefore, the recycling of e-waste has largely been left to informal recyclers. Overall, findings disclosed that due to its inept management, electronic waste has become an environmental threat to both Harare's environs and some of its inhabitants. It is in view of these findings, that the study recommends that there be: (i) specific legislation on the management of e-waste in Zimbabwe, (ii) Public Private Partnerships (PPPs) in the management of e-waste, (iii) a model for proper e-waste management be developed to guide the management of e-waste, and (iv) that people be educated on the dangers of e-waste and the importance of its proper management.*

**Keywords:**

Electronic

E-waste

Heavy metals

Dumpsite

Pollution

Recycling

Management

Harare

Zimbabwe

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# ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| °C | Degrees Celsius |
| As | Arsenic |
| BAN | Basel Action Network |
| BFRs | Brominated Flame Retardants |
| BWMPC | Botswana Waste Management and Pollution Control |
| CAQDAS | Computer Assisted Data Analysis Software |
| Cd | Cadmium |
| CMED | Central Mechanical Engineering Department |
| Co | Cobalt |
| CPU | Central Processing Unit |
| CRT | Cathode Ray Tube |
| Cu | Copper |
| DNA | Deoxyribonucleic Acid |
| Dstv | Digital Satellite Television |
| ECM | Environmental Citizenship Model |
| EEE | Electrical and Electronic Equipment |
| EIA | Environmental Impact Assessment |
| EM | Ecological Modernisation |
| EMA | Environmental Management Act |
| EMAL | Environmental Management Agency Laboratory |

| | |
|---|---|
| EPT | Expectancy Theory |
| EPR | Extended Producer Responsibility |
| ERB | Environmentally Responsible Behaviour |
| ESM | Environmentally Sound Management |
| *et al* | and others |
| ET | Expectancy Theory |
| EU | European Union |
| Fe | Iron |
| GHRA | Greater Harare Residence Association |
| GIS | Geographical Information system |
| GPI | Greenpeace International |
| H I Cs | High Income Countries |
| HBM | Health Belief Model |
| HCC | Harare City Council |
| Hg | Mercury |
| HIV | Human Immune Virus |
| HS | Harmonized Commodity Description and Coding System |
| ICT | Information Communication Technology |
| IEJ | International Environmental Justice |
| ILO | International Labour Organization |
| IPP | Integrated Product Policy |

| | |
|---|---|
| IPR | Individual Producer Responsibility |
| IT | Information Technology |
| Kg | Kilogram |
| LCA | Life Cycle Assessment |
| LCD | Liquid Crystal Display |
| LEDs | Light Emitting Diodes |
| LEP | Look East Policy |
| LMIC | Low and Middle Income Countries |
| MCA | Multi Criteria Analysis |
| MEEM | Model for Effective E-waste Management |
| MFA | Material Flow Analysis |
| Mn | Manganese |
| NEMA | National Environmental Management Act |
| NEP | New Environmental Paradigm |
| Ni | Nickel |
| NSSA | National Social Security |
| OHSA | Occupational Health and Safety Act |
| PAHs | Polycyclic Aromatic Hydrocarbons |
| Pb | lead |
| PCBs | Printed Circuits Boards |
| PCDDFs | Polychlorinated Dibenzodioxins and Furans |

| | |
|---|---|
| PCs | Personal Computers |
| PH | Potential Hydrogen |
| PHA | Public Health Act |
| POPs | Persistent Organic Pollutants |
| POTRAZ | Postal Telecommunication Regulatory Authority of Zimbabwe |
| PPE | Personal Protective Equipment |
| PPP | Public Private Participation |
| PPPs | Public Private Partnerships |
| PSP | Private Sector Participation |
| PTSs | Persistent Toxic Substances |
| RERA | Responsible Electronic Recycling Act |
| SADC | Southern African Development Community |
| SAZ | Standards Association of Zimbabwe |
| SDGs | Sustainable Development Goals |
| SEPA | Swedish Environmental Protection Agency |
| SET | Social Exchange Theory |
| SI | Statutory Instrument |
| SPSS | Statistical Package for Social Scientist |
| SSA | Sub-Saharan Africa |
| ST | Stakeholders' Theory |
| SVTC | Silicon Valley Toxic Coalition |

| | |
|---|---|
| TPB | Theory of Planned Behaviour |
| UN | United Nations |
| UNDP | United Nations Development Programme |
| UNEMG | United Nations Environmental Management Group |
| UNEP | United Nations Environmental Programme |
| UNESCO | United Nations Educational Scientific and Cultural Organization |
| US | United States |
| USEPA | United States Environmental Protection Agency |
| VBN | Value Belief Norm |
| WCED | World Commission on Environment and Development |
| WEEE | Waste Electrical and Electronic Equipment |
| WHO | World Health Organization |
| WOT | Waste Over Time Model |
| ZAEMA | Zambia Environmental Management Agency |
| ZELA | Zimbabwe Environmental Lawyers Association |
| ZEMA | Zimbabwe Environmental Management Agency |
| ZESA | Zimbabwe Electricity Supply Authority |
| ZIMRA | Zimbabwe Revenue Authority |
| Zimstat | Zimbabwe National Statistics Agency |
| ZINWA | Zimbabwe National Water Authority |
| ZISA | Zimbabwe Informal Sectors Association |

| | |
|---|---|
| Zn | Zinc |

# Chapter 1

## THE PROBLEM AND ITS SETTING

### 1.1 INTRODUCTION

This first chapter seeks to launch the study. It presents the background to the research, a concise statement of the problem, as well as the study's main and specific goals and research questions. The significance, delimitation, limitations, and mitigations of which the study follow. Lastly, the study's assumptions, its organisational framework, the definition of key terms as well as chapter summaries conclude the chapter.

### 1.2 BACKGROUND TO THE STUDY

The ever-increasing human disposition for electronic and electrical gadgetry as fuelled by globalization, modernization, and more recently, the advent of the Fourth Industrial Revolution, has notably spawned the term: e-waste. E-waste has over the years been severally defined. For some, it entails electronic equipment and or parts of such that are obsolete and have been discarded by the owner with no intention or motive to reuse them (Roychowdhury, *et al.,* 2016). For others like Kozlan (2010), trash from old electronics, appliances, and gadgets is what is regarded as e-waste and it is also defined as waste electrical and electronic equipment (WEEE). According to Niranjani (2014) electronic waste, e-waste, e-scrap, or waste electrical and electronic equipment describes loosely discarded, surplus, obsolete, broken, electrical or electronic devices. Borthakur and Sinha (2013) indicated that WEEE illustrates discarded appliances that utilize electricity for their functioning. WEEE or e-waste is often misunderstood to refer only to computers and related IT equipment. In the study, this scholar regards WEEE as either 'white goods' which are household appliances such as refrigerators and dishwashing machines, 'brown goods' like television and cameras, and 'grey goods' such as printers and scanners.

On the African continent, the same human disposition to acquire the latest technology has over the years also seen a marked rise in the importation and acquisition by Africans of electronic and electrical goods from the developed world. After which the increase in e-waste has also become a feature of some developing countries. In 2014 the amount of e-waste generated in Africa was 1.9 million tonnes (Balde, *et al.,* 2015). However, whereas a few developing countries such as Nigeria and Cameroon have crafted and implemented both legislative and strategic measures to manage e-waste, most African countries have not done so. It is against this backdrop, that this study sought to assess e-waste management in Harare, Zimbabwe to establish the vital considerations for an effective e-waste management model.

During the past few years' electronic technologies have been gradually incorporated into every task performed every day worldwide, (Malhotra, 2011). Tremendous economic development in some developing countries has brought about the unprecedented acquisition of electronic and electrical products which over the years have compounded e-waste generation. This dictates that research and e-waste proper management legislation, strategies, and tools be availed.

However, despite the increased global concern about e-waste management, the search for what to critically consider for the drafting and implementation of an effective e-waste management model for developing countries has remained under-researched by many studies. Significantly, there is no inventory for electronic waste management in Zimbabwean cities. This includes Harare, Zimbabwe's capital city. As Smith *et al.,* (2013) noted, the lack of environmentally sound e-waste management systems is almost the norm on the African continent. In Zimbabwe's case, the effectiveness of existing institutions to manage e-waste has been widely questioned since management frameworks for e-waste management seem to have failed to achieve set policy targets (Mandevere, 2016; Maringe, 2016). Despite some studies on environmental management and e-waste management, such as "E-waste in Zimbabwe and Zambia by Gweme (*et al.,* 2016) as well as “A Situational Analysis of Waste Management in Harare, Zimbabwe by Tsiko and Togarepi (2012), none of these studies have assessed e-waste management in any of Zimbabwe's towns or cities with the view of establishing the vital considerations for effective e-waste management model for cities in developing countries.

Recent research indicates that developing countries lag far behind in terms of developing e-waste management strategies yet, e-waste contains more than 1000 different substances most of which are toxic (Ozturk, 2015; Barthku, 2014). Only Cameroon and Nigeria have enacted national e-waste related legislation in Africa. South Africa is working on a model for e-waste management (Blade, *et al.,* 2014). It is very difficult to ascertain the state of e-waste management preparedness on the continent as very few governments' reports on electronic waste are available in Africa (Ongondo, *et al.,* 2011). This at least makes a city-specific assessment and documentation of its e-waste management approach progressive, especially towards an under-researched area of Environmental Science.

The electronic industry is one of the fastest-growing in the world. The global market of electrical and electronic equipment (EEE) continues to produce exponentially while the life span of the products continues to shorten daily (Chaurasi, 2014). Fastest growing waste stream in the world with a growth rate of 3 to 5% (Balde *et al.,* 2017). Approximately 9% of the total e-waste is made of hazardous substances such as lead, cadmium, mercury, and other toxic chemicals (Meltzer, 2014). The cost of recycling e-waste out passes the revenue recovered from material especially in the countries where environmental regulation is strictly followed. Thus, e-waste is a serious problem in developing countries where environmental standards are low and poor.

Manufacturers of such gadgets tactically plan the obsolesce of their products by rapidly introducing new ones with better features such as Liquid Crystal Display, (LCD), screens that have now replaced Cathode-Ray Tubes (CRT). This simply means the mushrooming of e-waste whose management is unknown or scarce in cities of the developing world (Balde *et al*., 2017; Malhotra, 2011). This calls for the need to conduct site-specific audits of the effectiveness of e-waste management practices. The effectiveness of current e-waste management practices to deal with rapid changes in e-products and the increased generation of e-waste have remained unquantified in most economic environments particularly in developing countries.

Electronic waste-related heavy metals are dangerous to both the biotic and abiotic environment (Namias, 2013). Electronic waste is believed to be a topical environmental threat. The world over, particularly in most developing countries its management is marred with a multiplicity of problems (Sitaramaiah, *et al.,* 2014). Acute pollution might cause diseases, sterilize the entire population and produce genetic defects in future generations (Williams, 2012). Although the cataclysmic consequences of e-waste pollution are remote, they should not be ignored (Williams, 2002). This is because continuous mismanagement of e-waste will result in the accumulation of toxins which will become harmful to the environment as well as its inhabitants. This study therefore critically reviews current e-waste practices in Harare, the capital city of Zimbabwe. Insights from such an audit would be used to establish the vital considerations of a model for effective e-waste management for cities in developing countries.

Mutsau (2015) indicated that the rate of technological change has created an appetite for replacement behaviour among consumers leading to the proliferation of e-waste. This has created a rapid rise in the generation of electronic waste in Harare, Zimbabwe (Matsau, 2015) resulting in associated problems. The effects of heavy metals affect the body when consumed above the recommended limits thus causing such health problems as: Cancer; Gastrointestinal disorder; Stomatitis; Pneumonia; mutagenic or teratogenic and neurotoxic problems.

This is against the fact that the Environmentally Sound Management (ESM) of e-waste in most developing countries is absent or at best very limited (Herat and Pariatamby, 2012). Obsolete or damaged Electrical and Electronic Equipment (EEE) is not recycled or repaired but more likely is simply thrown away and thus in water or on land causing pollution. Waste Electrical and Electronic Equipment (WEEE) is growing at an average rate of 4% per year (ILO, 2012). Such an increased rate of growth is causing serious pollution to the environment and critical is the fact that about 25% of the earth is covered with water and hence pollution of water bodies by heavy metals, not to mention health effect on human beings and other forms of life on earth.

In recent years, the energy demand has seen the rise of solar as an alternative source of electricity. Despite this, it must however be noted that solar cells contain certain silicon tetrachloride, cadmium, and selenium among other substances (McAlister *et al.,* 2014), and batteries contain lead-acid, zinc-bromine, beryllium, cadmium, chromium, lead, and mercury brominated flame retardants (BFRs), all of which are dangerous to both the environment and human health. What therefore appears to be a solution, is another problem. It is estimated that by 2040 all solar panels currently in use will be entering the e-waste stream (McAlister *et al.,* 2014). In this regard, the most attractive technological solutions to climate change such as solar energy and electric battery cars will add to the rapidly growing stream of e-waste (McAlister *et al.,* 2014). Electronic waste management is urgently required if sustainable development in developing countries is to be accomplished.

Several models which try to explain the phenomenon of e-waste have been propounded. The Waste Over Time Model (WOT) proposes that e-waste or any other form of waste increases with time due to different factors. These include among others: population size, available management options, and availability of waste management facilities, political will, economic abilities, and others. For others however, there is yet no universally accepted definition for electronic waste available. While several definitions have been advanced in a bid to explain the phenomenon, their multiplicity makes it even more difficult to positively assess the amount of e-waste that is produced or shipped globally. It is however accepted that its quantity can be calculated using the equation: TEDQ + I (di + si) - E = EWQ. Where:

TEDQ = Total Electronic Domestic Quantity

I = Imports of electronic goods

d I = declared imports of electronic goods

s i = smuggled imports of electronic goods

E = Exports

EW Q = Electronic Waste Quantity

Source: Author's Construct, (2019)

However, the key components of the equation presented above are almost non-existent in most developing countries such as Zimbabwe. This makes it difficult to develop effective management frameworks. It is in the light of this, that the study sought to assess the existing e-waste management frameworks to develop a feasible waste management model for the City of Harare.

Globally, conventions such as the Basel, Bamako, Minamata and others have been crafted to alleviate the challenges of e-waste. Most countries, besides having their own local institutions of management, are signatories to these international conventions. However, most of these local regulations have fallen by the wayside either due to lack of stakeholder will or defects inherent in the law itself. In Zimbabwe, the Environmental Management Act (EMA), Chapter 20:27 of 2002 is the most powerful environmental law of the country whose mandate is to stop and or control the discharge of hazardous substances into the environment. However, its shortcoming is that the Act does not regard e-waste as a special form of waste. Electronic waste is rather labelled as any other hazardous waste with no special treatment in the Act or any other law. This is averse to the fact that ILO (2012), indicated that e-waste is currently the largest growing waste stream, which is hazardous, complex, expensive to treat, and should be managed accordingly. Hence the need to critically look at e-waste management in Harare, Zimbabwe.

Developing countries such as Ghana, Zimbabwe, Zambia, and others have been made extended dumping grounds for e-waste by the developed world (Sitaramaiah, *et al.,* 2014). Namias (2013) laments that nearly 80% of e-waste meant for recycling in some developed countries find its way to developing countries, either legally or illegally, leading to increased environmental pollution at the destination. While developing countries receive large volumes of electronic goods from the developed world, they do not have proper e-waste management skills and technologies (Oteng-Ababio, and Amankwaa, 2014) to process them. A lot of electronic goods generated in their environment through local production and imports are also contributing to the pool of e-waste. This problem means, Harare will be or is already faced with a formidable task of managing its e-waste and hence the need to critically evaluate the current e-waste management approaches. Slideshare (2015) further posits that e-waste contains heavy metals that can be harmful to the human body, and the ever-increasing demand for electronic items leads to an alarming rate in e-waste generation. Such a situation calls for an audit of existing institutions of e-waste management to understand their effectiveness and undertake corrective measures if there is a need to.

The electronics industry is the largest and fastest-growing manufacturing industry (Bhuie *et al.,* 2004) in the world. In particular, ICT has gradually but steadily permeated virtually every facet of our lives especially with the coming of the electronic revolution. Developing countries are struggling to deal with e-waste and according to Li *et al.,* (2014) manufacturing of electronic products from developed countries is taking advantage of the absence of the lack of environmental laws in developing countries to dump and pollute their environment.

The frequent change in the types of electronic goods, driven by the demand for efficiency has increased the rate of e-waste generation. Such rapid changes have resulted in the generation of e-waste at a much faster rate and pace than the capacities of many cities across the world, particularly in the developing world to handle it. This has further been complicated by an ever-increasing population that is always demanding new electronic goods. Especially as technology keeps calling for the birth of new electronic goods, some of which have a very short life span as the business community tries to make a profit by producing items whose life span is short.

Current research has shown that it is a continuous struggle to manage e-waste in developing cities like Harare. The global figures on e-waste show a bulging environmental problem. This is more so because the developed countries export to developing cities already old electrical and electronic goods in the name of bridging the digital divide. In so doing, the developing cities like Harare become overwhelmed by its management, and this ends up polluting the environment and affecting human health. The assumption that the physical environment can transform e-waste dumped to it, without it being negatively affected, cannot, therefore, be ignored and be allowed to proliferate. It is in this context that this project seeks to critically look at the management of e-waste in Harare, Zimbabwe.

The removal of heavy metals from the soil and water once contaminated, is extremely expensive, if not impossible, and the treatment of heavy metal-related illnesses is also difficult (Jaishankak, *et al.,* 2014). This means electronic waste management needs to be dealt with before its contaminants complicate an already complicated waste management system. There is no law on the generation or importation of electronic goods, or the recycling, as well as general governance of the handling of e-waste in Zimbabwe. Zimbabwe has not domesticated the Bamako and Basel conventions yet, thus complicating e-waste management (Makwara and Magudu, 2013). This probably explains why currently government departments have skeletal information on e-waste management in Harare. This means that there is a need for research that looks at the management of e-waste in Harare covering even those areas known to be least affected by such.

In most developing countries, 50% of the population lives in cities (Balde *et al.,* 2017). It is often assumed that the urban population is wealthier than the rural population and suffers more than its urban counterparts. Recent research however shows that the urban poor suffer for living in urban areas as they are affected by the improper recycling of e-waste and end up exposed to heavy metals (Sitaramaiah *et al.,* 2014). The number of "mega, million and billion" cities is growing but also medium-sized and smaller urban agglomerates are experiencing explosive growth and the pressure on the urban areas has increased dramatically leading to poor e-waste management and its associated environmental and health problems. This has seen 25% of all the death in developing regions being attributed to environmental causes and only 17% of death attributed to such causes in developed regions (WHO, 2006).

Developing countries are facing a multiplicity of environmental problems (Namias, 2013). Of note is the massive generation of background e-waste and lack of legislation, education on the dangers surrounding e-waste and proper disposal facilities, as well as lack of recycling technologies and capacities (Balde, *et al.,* 2014). This is a serious problem that requires an urgent and immediate solution, this means that e-waste management in Harare, Zimbabwe needs to be looked at closely as these predicaments are manifesting in most cities in developing countries (Ongondo *et al.,* 2011). In most developing countries, due to a lack of proper e-waste management frameworks, e-waste is either burnt in open spaces or dumped at undesignated places. This problem still stands despite attempts by waste management authorities to manage the e-waste using longstanding collection and waste minimization strategies (Chirisa, 2012). There is, therefore, a need to critically assess the effectiveness of e-waste management practices in Zimbabwe, Harare in particular.

In Zimbabwe's Harare, the levels of e-waste related toxins in different areas remain unknown. This calls for the need to conduct soil and water testing from various areas and sources of water around Harare such as dumping sites, rivers, boreholes, wells and streams passing through Harare and major sources of water for Harare such as Lake Chivero, to comprehend the extent, the level of e-waste pollution and the effectiveness of current e-waste management approaches. Once there is a picture of e-waste levels and distribution in Harare, it will then be possible to develop a model for effective e-waste management.

The rise of the electronic revolution attributable to human ingenuity and advances in technology has seen an increased demand in the use of electronic goods. In Harare, this has resulted in increased e-waste generation as evidenced by the indiscriminate disposal of e-waste along roadsides, on open spaces, and other undesignated sites. This not only reflects an incapacity to manage e-waste but also retardation of sustainable development and health goals for all by the year 2030 (Chirisa, 2012).

Chidavaenzi, (2006) indicated that urban growth in Zimbabwe continues at a much faster rate than the provisions and expansion of infrastructure that are critical to waste management. This will thus, complicate e-waste management in future. Mudzengerere and Chigwenya (2012) pointed out that despite the large population, municipals charge very nominal fees that in some cases fail to even cater for the operational costs and worse so the construction and hiring of critical structures to manage waste properly.

This is further complicated by e-waste a new child in the waste management process, whose production is more than two times the production of other forms of waste.

It is therefore inevitable for one to conclude that e-waste requires an estimation of the immediacy, magnitude of the danger, and the cost of remedying the situation (Balde, *et al.,* 2015), as this will help in the management of e-waste.

**1.3 STATEMENT OF THE PROBLEM**

The tremendous economic development in developing cities has seen the birth of the electronic revolution and industry. The electronic revolution which is a product of human ingenuity has increased demand for electronic goods so much so that the quality of such products has been compromised resulting in increased e-waste generation the world over. Unfortunately, this e-waste management predicament is mostly affecting developing cities like Harare in Zimbabwe as they cannot manage e-waste effectively. Consequently, the city of Harare, has witnessed a multiplicity of illegal e-waste dumpsites. Evidently, e-waste is on the rise in the city of Harare. In the light of this, what e-waste management systems, strategies and legislation does the metropolis have in place, how effective are they and what impact has e-waste had on both the environment and forms of life that is in close proximity to the city's dumpsites, what considerations should be considered to come up with an appropriately effective e-waste management model for the city?

Despite a plethora of studies on waste management, more can still be contributed as this form of waste is steadily becoming topical (Namias, 2013; Smith *et al.*, 2013; Sitaramaiah, *et al.,* 2014, andAtiemo *et al.,* 2017). Notably, however, the effectiveness of the City of Harare's current e-waste management approaches remains researchable. While a comprehensive and systemic review of the literature reveals that scholars have developed and proposed models for the sustainable management of e-waste value chains in developing countries, (Maphosa and Maphosa., 2020; The E-waste Training Manual., 2019; Atiemo *et al.,* 2017; Heeks*et al.,* 2015; Oteng-Ababio and Amakwaa., 2014; Sitaramaiah, *et al.,* 2014; Schluep, 2010), a close analysis of these studies on e-waste management in developing countries reveal the existence of a gap in the search for a model for effective electronic waste management; in particular for Zimbabwe.

The absence of proper mechanisms, regulations, and standards of disposal makes e-waste end up in a 'normal' waste stream meant for all other forms of solid waste. Studies conducted to date have mainly focused on global sources of e-waste (UNEP, 2013; Balde *et al.,* 2017; ILO, 2017); state of global e-waste (Namias, 2013; UNEP, 2008; Sitaramaiah *et al.,* 2014; Balde *et al.,* 2017; ILO, 2014); state of e-waste in developed countries (Oteng-Ababio, 2012; Sitaramaiah *et al.,* 2014; Meltzer, 2014; Balde, 2010; Makwara, 2013); state of e-waste in developing countries (Balde *et al.,* 2015; 2017; Sitaramaiah *et al.,* 2014); effects of e-waste (Oteng-Ababio, 2012; Jaishankak et al., 2014; Balde et al., 2017; Rao, 2014; Rayputje, 2013; Panda, 2013; Mahurpawar, 2015), laws and conventions on e-waste (Namias, 2013; ILO, 2017) and challenges in e-waste management (Zerbock, 2003; Jerie, 2006; Meltzer, 2014). These studies overlook the need to develop a model for effective e-waste management in cities in developing countries such as Harare, Zimbabwe. Without an appropriate model for e-waste management, the e-waste management problem will increase resulting in exacerbated pollution and disease. Therefore, this study used pragmatism to develop a model for effective e-waste management. The study findings besides extending the frontiers of knowledge and testing theory in terms of scope and veracity on effective e-waste management practices could be used to inform policy on effective e-waste management.

Despite having environmental management institutions in Zimbabwe and several environmental management regulations, such as the EMA (Chapter 21:07), Public Health Act, (Chapter 15:09), Water Act (Chapter 20:22), and others, none of these acts directly mention e-waste management. This means that e-waste is regarded as any other form of waste despite the environmental and human health problem possessed by the heavy metals it carries. The upsurge and boom in the generation of e-waste require that this environmental problem be given attention while it's still budding. (Ezeah, 2010).

In recent years, the energy demand has seen the birth of solar energy as a solution, it must however be noted that solar cells contain certain silicon tetrachloride, cadmium, and selenium among other substances (McAlister *et al.,* 2014), and batteries thereto contains lead-acid to zinc-bromine, beryllium, cadmium, chromium, lead, mercury brominated flame retardants (BFRs) all of which are dangerous to both the environment and human health. Thus, the most attractive technological solutions to climate change such as solar energy and electric battery cars will add to the rapidly growing stream of e-waste (McAlister *et al.,* 2014). This means electronic waste management is a real problem that requires proper attention if sustainable development is to be accomplished especially in developing countries. It is in the light of this that it is imperative to timeously and proactively undertake this research to ensure that Harare and Zimbabwe are advised accordingly about the dangers of e-waste and how it should be managed because 25% of all the death in developing regions are attributed to environmental causes (WHO, 2006).

## 1.4 MAIN OBJECTIVE

To develop a model for effective electronic waste management in Harare.

### 1.4.1 Specific objectives of the study

The specific objectives of the study were to:

i. Assess electronic waste management (e-waste) strategies being used in Harare.

ii. Review the existing environmental laws concerning electronic waste management in Zimbabwe.

iii. Establish the effectiveness of available electronic waste management strategies being used in Harare by testing for heavy metals in water and soils.

iv. Establish the population of Harare's understanding of the phenomenon of e-waste management.

v. Develop a relevant model for effective electronic waste management for Harare.

## 1.5 MAIN RESEARCH QUESTION

What model can be developed for effective electronic waste management in Harare, Zimbabwe?

### 1.5.1 Specific research questions

This study sought to address the following research questions: -

i. What electronic waste management approaches are being used in Harare?

ii. What are the existing environmental laws on electronic waste management in Zimbabwe?

iii. How effective are the electronic waste management strategies being used in Harare?

iv. What is the level of the population of Harare's understanding of the phenomenon of e-waste management?

v. What model can be developed for effective e-waste management in Harare?

## 1.6 SIGNIFICANCE OF THE STUDY

Globally, the generation of e-waste has witnessed a general increase (Meltzer, 2014 and Atiemo *et al.,* 2017, The E-waste Training Manual., 2019). Available statistics indicate that the annual generation of e-waste has grown to 44.7 Million Metric Tonnes globally (Global E-Waste Monitor, 2019). This amounts to 6.1 kilograms (kg) of e-waste generated by each individual yearly, which is expected to increase to 6.8 kg by 2021 (Global E-Waste Monitor 2019). When looked at, such figures inevitably lead to the conclusion that the future of human society and perhaps even the survival of humanity depend on the speed and effectiveness with which the world responds to issues like e-waste pollution (Tsiko *et al.,* 2012). Human survival depends on avoiding any foreseeable risks. This research work aimed at establishing the vital considerations for best practices in e-waste management for cities in developing countries. Generally, environmental legislation and its enforcement in Africa have been known to be poor

(Achankeng, 2003). E-waste is omnipresent and generated everywhere and the developing countries bear the greatest burden of adverse health hazards and ecosystem degradation, prolonging their achievement of sustainable development goals (Radha, 2002). This simply means there is a need to complement the few pockets of emerging ideas on e-waste management to bridge the gap between rhetoric and practice.

There is no inventory of e-waste and its management in most cities in developing economies. The phenomenon is managed like all other forms of waste. This study sought to contribute towards the treatment of e-waste as a stand-alone field of focus. Such a separation and treatment of e-waste from other forms of waste is important for its growth as an area of research interest.

The consumption of electronic products driven by manufacturers' aggressive marketing strategies has sky-rocked. However, the drawback has been the short lifespan of most of these electronic products. In developing countries, for instance, the life cycle of most mobile phones is reportedly less than two years (Greenpeace, 2002). Compounding the situation has been the drive by most developed countries to make developing countries their extended dump sites. Such relationships in favour of the High-Income Countries (HICs), raises issues of the value of such marriages of convenience. Thus, although a lot has been done on e-waste, no study known to this researcher has queried best practices in e-waste management. The current study results will query such issues to develop a model for effective e-waste management.

The problem of e-waste management has serious ramifications on the health system of any country. The problem of e-waste management manifests itself in several ways. The ever-growing illegal settlements across Harare have exposed people to water poisoning (Makwara and Magudu, 2013). Lack of service provision has meant that such mushrooming communities' resort to shallow open wells for water. These open wells expose people to metal poisoning as the underground water might be polluted. Such risks call for an audit of the existing frameworks for e-waste management to avert likely environmental and health disasters.

The Zimbabwean government's Look East Policy (LEP) has also stimulated an unprecedented inflow of electronic goods from China. The problem has been the short life span of most of these electronic goods further compounding the e-waste management problem to the already burdened town council. How well the existing structures have been able to cope with this extra burden remains a virgin area for study, hence the value of this study.

The environment is a very critical habitat for life and elements of the environment, such as water, air and soil should be protected to avoid pollution. However, research conducted in other environments highlights that e-waste is a threat to these habitats (Jibril *et al.,* 2012; Atiemo *et al.,* 2016; Balde *et al.,* 2017; E-Waste Training Manual, 2019). This means that e-waste management issues need to be addressed timeously (Jibril, *et al.,* 2012).

Statistics from Zimstat, (2012) indicate that the estimated population of Zimbabwe is 16,303,387 with over 1,200,000 mobile phone subscribers. This means that on average, there are more than 10 electrical gadgets in each urban household (Zimstat, 2012). Statistics indicate a high generation rate of electronic waste especially in Harare, being the capital city. Such high volumes of electronic gadget use require an audit of the existing frameworks for electronic waste management.

If the present trends in the world population, industrialization, and pollution continue unchanged there will be serious e-waste pollution that threatens the environment and humanity (Sitaramaiah, *et al.*, 2014). Currently, much of the e-waste in Harare is coming from imports of electronic goods from developed countries and other countries such as China, Dubai among others. Amidst the increase in consumption of electronic goods, research has been almost silent on the effectiveness of current approaches for e-waste management. Thus, the value of this study is to act as a reference resource to policymakers and an effective e-waste management model for Zimbabwe.

Heavy metals, most of which are contained in e-waste are a threat to the biotic and abiotic environment (Namias, 2013). The current study will therefore contribute towards informing relevant government institutions, such as the: Ministry of Health and Child

Welfare, ZINWA, Zimbabwe Environmental Lawyers Association (ZELA), Ministry of Lands and Agriculture, ZEMA, Ministry of Environment Water and Climate, Ministry of Local Government and local authorities, as well as non-governmental organizations, national and international organizations of the need to ensure that e-waste is well managed and disposed of to ensure environmental accountability.

E-Waste produces a higher volume of waste in comparison to other consumer goods. As such, the e-waste management problem remains central. (Malhotra, 2011; Sunshant*et al.,* 2010). Emerging and notable research on the existence of an e-waste problem in the Zimbabwean context include that of Gweme *et al.,* (2016), Tsiko and Togarepi (2012), who variously assessed the effectiveness of existing frameworks for e-waste management in the country. Therefore, the thrust of this study was to conduct a critical review of these frameworks to develop a feasible model for managing electronic waste.

The examination of the spatial patterns of electronic waste in Harare is nascent and open for contribution. The collection and analysis of data of the city's e-waste situation will bring to the fore the scale of the problem. The results of the study would inform planners to come up with informed e-waste management mechanisms.

The rate at which the world has shrunken into one small village, due to modernization and the birth of the electronic revolution, has seen a proliferation in the manufacturing of sub-standard electronic goods whose cradle to grave life expectancy is too short. The gestation of electronic gadgets is so fast that the models of such are trickling in daily, exceeding the availability of resources and knowledge to handle these when they become obsolete. Many chemicals in electronic devices are environmentally persistent, meaning they remain in the environment for long periods once released. This situation entails the need for research to guide the city and other small cities in similar situations to mirror a possible future catastrophe and devise mechanisms to reduce the pace at which electronic waste is polluting the environment.

Harare does not have properly managed landfills that are capable of preventing underground water contamination (Mandevere, 2016). The current scenario is one of dumping at the official dumpsites of Pomona and Golden Quarry that are not lined. One wonders about the levels of pollution in a city whose dumpsites are home to all kinds of waste including electronic waste. There was therefore a need to conduct soil and water assays around dumpsites in Harare to establish the levels of electronic waste pollution. Merely imagining the number of television sets, cell phones, cars, computers, and other e-waste carrying gadgets in Harare and how these are handled when they become e-waste, left one with a lot of unanswered questions regarding the future of the environment and people's health in general, especially in the face of the dangers posed by e-waste. Therefore, information on the current and possible future state of the environment is critical as it helps in the planning of environmental management in Harare, Zimbabwe.

The fact that most developing countries have limited resources to handle their waste (Medina, 2010) means that the management of e-waste is marred by a lot of problems. The lack of adequate resources to handle different kinds of waste has resulted in all forms of waste being dumped in a single dumpsite. This has denied other forms of waste such as electronic waste proper treatment. Consequently, dangerous substances are being deposited into the environment. As such, one might conclude that the electronic waste problem has resulted in a multiplicity of environmental problems that need to be looked at closely to advise the city and the nation at large. The figures that have been published globally on e-waste clearly show that humanity and the environment are at risk, hence the need to critically evaluate the e-waste management approaches being practiced in Harare. This would illuminate the gap between rhetoric and practice, and allow tailor-made solutions to be developed.

According to Mukoki, (2015) there has been an exponential growth of e-waste in developing countries. The number of electronic gadgets has proliferated immensely during the last decade. Zimbabwe has additionally seen an upsurge in e-waste due to the coming in of electrical and electronic goods from countries like China. There have been increased electronic goods to Africa (Mlambo, 2013). Zimbabwe is grappling with the challenge of reducing levels of unsafe disposal and processing of e-waste. However, Gweme, *et al*., (2013) indicated that countries in Africa cannot handle and recycle the hazardous material contained in e-waste. To present, no inventory has been made to assess the extent of e-waste problems and the effectiveness of e-waste management in use in Zimbabwe (Gweme, *et al.,* 2013). Zimbabwe does not have a government-approved e-waste recycler specifically licensed to collect, process, and ship e-waste. This is why this study sought to assess the effectiveness of existing e-waste management approaches in Harare. The findings would be used to develop a model for the effective management of electronic waste in Harare and Zimbabwe in general.

## 1.7 DELIMITATION OF THE STUDY

Delimitation of a study are features that can be managed to determine the scope or parameters of the phenomenon under study (Creswell, 2013). Therefore, the following are the delimitation for the current study:

### 1.7.1 Conceptually

The issue of intellectual curiosity in this study was to develop a model for effective e-waste management in Harare.

### 1.7.2 Geographically

The study was conducted in Harare, Zimbabwe.

### 1.7.3 Methodologically

This study adopted a mixed research methodology as one of the objectives required statistical measurement of one variable over another. The qualitative approach was used to gain insights from stakeholders on how to develop a model for the effective management of electronic waste in Harare and Zimbabwe in general.

### 1.7.4 Philosophical Delimitation

In this research study, pragmatism was used to guide the study. Pragmatism is regarded as the philosophical partner for the mixed methods approach. It provides a set of assumptions about knowledge and inquiry that underpins the mixed methods approach and which distinguishes the approach from purely quantitative approaches that are based on a philosophy of (post) positivism and purely qualitative approaches that are based on a philosophy of interpretivism or constructivism (Saunders *et al.,* 2013). The positivism philosophy was used to measure the levels of water and soil pollution around dumpsites and other areas in Harare whilst the phenomenological stance was adopted in this study to develop a model for effective management of electronic waste.

#### 1.7.5 Respondents for the Study

The researcher categorised respondents into: (1) Experts from various Government Institution, parastatals, Non- Governmental Organisation, and other institutions (2) Members of the Public to include households, motorist, shop customers, and (3) (Formal) Recyclers and Informal recyclers, electronic goods selling shops and other relevant bodies/individuals with relevant knowledge to the phenomenon under study. Interviewees were purposively selected and others were randomly picked.

### 1.8 LIMITATIONS AND MITIGATIONS

The researcher had no control over the social environment in which the study was carried out. Therefore, institutional policies, customs, cultural and religious norms, and values could not be underestimated in the selected study sites. Therefore, such environmental factors had to be observed within the selected study area.

Poor record-keeping rendered some archival information relevant to the study none available. The researcher had to rely more on published information for statistics to triangulate with interview gathered data.

### 1.9 STUDY ASSUMPTIONS

i. The e-waste management strategies being used in Harare are not known.

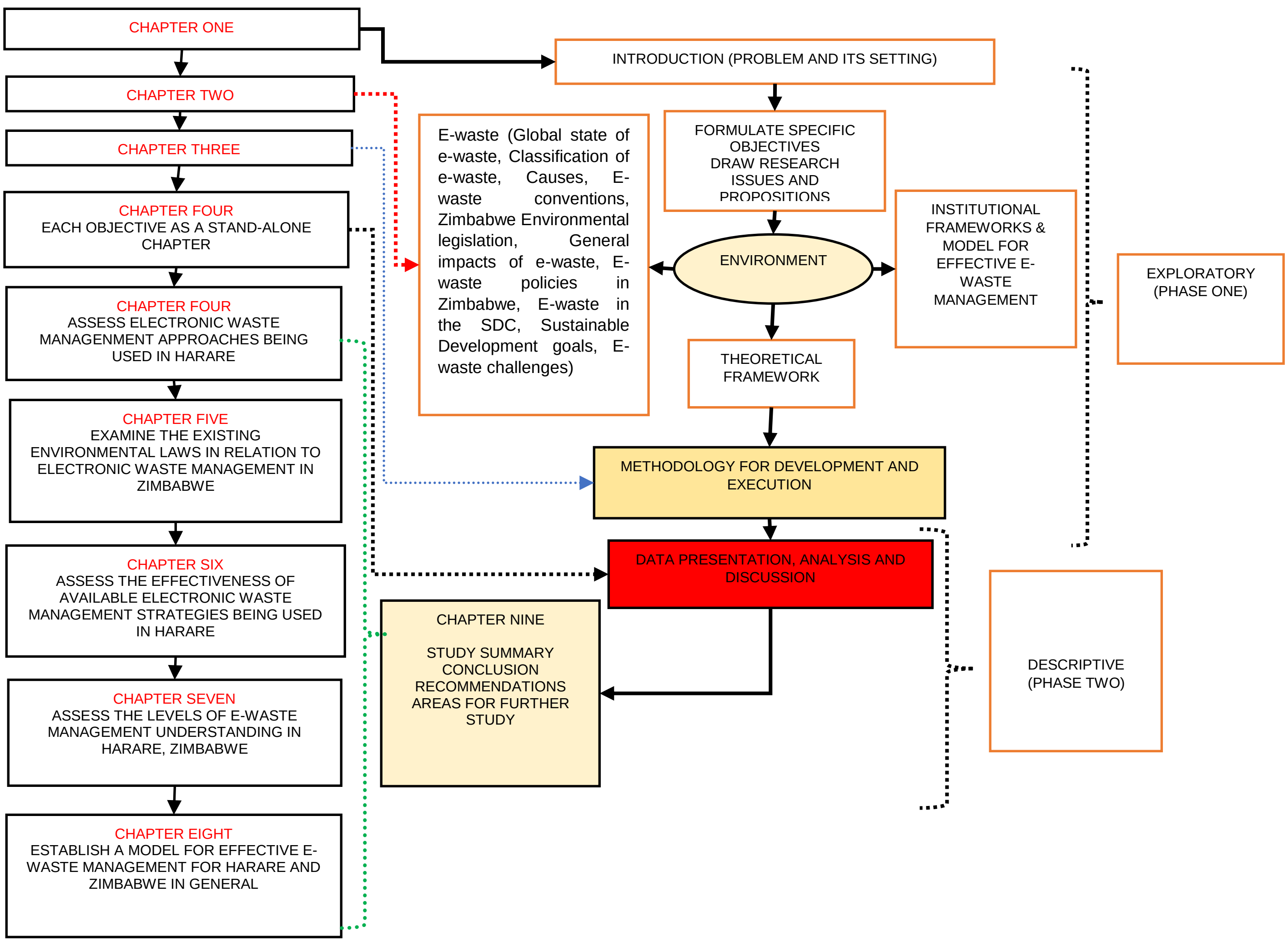
ii. Zimbabwe's current environmental laws are not adequate to address the problem of e-waste management.

iii. Available e-waste management practices are not effective.

iv. The population of Harare's understanding of the phenomenon, e-waste management is very poor.

## 1.10 THE RESEARCH ORGANIZATIONAL FRAMEWORK

Figure 1.1: Chapter Organization




Source: Adapted from Tustin (2005)

### 1.10.1 Chapter One

This is an introductory section that serves to present the background and orientation of the study as well as the research problem. The purpose of the study and the underlying research objectives that underpin the study stem from the background and the problem statement. This first phase of the research is going to be more exploratory as the study area is rather a new field of research particularly in the Harare and Zimbabwean context characterized by just a handful of researches done hence the absence of much-needed literature.

### 1.10.2 Chapter Two

This chapter is exploratory in nature as the researcher defines the research problem through a literature review in a bid to satisfy the demands of the research as presented by the research objectives. This section also includes a review of relevant theories that underpin the study. Theories in this study are the lens that facilitates our understanding of the processes, issues, and forces at play in the phenomena under investigation. This study derived illumination from a variety of inter-disciplinary theories such as: The Theory of Waste Management, Theory of Environmentally Responsible Behaviour, The Environmental Citizenship Theory, The Value-Belief-Norm-Theory of Environmentalism, and the Diffusion of Innovation Model. Each of these theories had explanatory validity in the study. The theories' significance is overarching as it helps to explain the interplaying factors which determine the effectiveness of e-waste management factors.

### 1.10.3 Chapter Three

This chapter serves to outline the research methodology for development and execution. It explains the research approaches adopted, the planning process as well as the intended research population, (sample size chosen). The data collection instruments and procedures followed are also outlined in this section to satisfy both research reliability and validity.

### 1.10.4 Chapters Four - Eight

This section of the study deals with the data collected, its interpretation, analysis, and presentation. The results presented and analysed build on the key elements and outcomes of the preceding chapters.

### 1.10.5 Chapter Nine

This chapter forms part of the descriptive section of the research study. This chapter presents the study summary, conclusion, and recommendations derived from the synthesis of the research findings. It also presents the implications of the research to the existing body of knowledge and presents knowledge gaps upon which other future research may build upon. This chapter is then followed by the reference section and the appendices.

### 1.11 DEFINITION OF KEY TERMS

The terms defined below include those that appeared more frequently in this study and in-depth analysis into the aspects to do with the terms was done in sections of the literature review.

**Dumpsite:** Commonplaces where waste is deposited without segregation or professional management; it is common in most developing countries and is usually not lined to reduce underground water pollution.

**Electronic Waste Pollution:** Contamination of the environment due to the heavy metals that are found in e-waste and other substances that are released in various forms when e-waste is dumped into the environment without proper treatment.

**Environment:** Biotic and abiotic surroundings.

**E-waste:** Entails electronic equipment and or parts of such that are obsolete and have been discarded by the owner with no intention or motive to reuse them in the day-in-day-out purpose for which it was created and should be disposed of.

**Heavy metal:** Dangerous metal substances found in electronic waste, which can contaminate and pollute the environment.

**Landfill:** A place where waste is deposited professionally with specialist management of the site. It is designed to ensure that the soil and water around it is not polluted due to the infiltration of dangerous toxins

**Pollution:** Contamination of the environment with harmful and undesirable substances.

**Population:** Number of people living within a given area.

**Soil:** The upper stratum of the earth

**Water:** A substance found at room temperature and pressure as a clear liquid, it is found as rain and in various sources on the earth's surface.

## 1.12 CHAPTER SUMMARY

This chapter discussed the problem and its contextual setting. The background to the study, statement problem, and aim of the study, scope, assumptions, delimitations, and limitations were also looked at. Objectives that the research study is based on were as well highlighted and the research questions to be answered in this study. To get an early understanding of the phenomenon under study, the key terms that establish the frame of reference with which this study was conducted were defined. This chapter was followed by eight other chapters. The next chapter reviewed the literature on the phenomenon under study.

# Chapter 2

## LITERATURE REVIEW

### 2.1 INTRODUCTION

This chapter reviews the literature on e-waste management for cities in developing countries. Specifically it reviewed literature on global waste classification, e-waste, the state of global e-waste, conventions on dangerous e-waste, e-waste generation per content, e-waste and its management strategies in developed countries, e-waste wheel of life, life cycle of e-waste; e-waste and women and children, disposal of un-usable and parts of e-waste at open dumps, surface waters, e-waste in developing countries, e-waste recycling in developing countries, sources of e-waste across the globe, Zimbabwe's laws and policies on e-waste, causes of poor e-waste management in Zimbabwe; population and waste generation, sustainable e-waste management, urban mining, incineration of waste, development theories and e-waste, challenges and opportunities of e-waste management, environmental laws in Zimbabwe, landfills and dumpsites, sustainable e-waste management principles, life cycle assessment (LCA), material flow analysis (MFA), multi criteria analysis (MCA); extended producer responsibility (EPR); The Life Cycle of e-waste; solid waste management of e-waste; health and safety in e-waste recycling; customer behaviour on e-waste; e-waste management and sustainable development; action to handle e-waste; sustainable development goals (SDGs) and waste management. However, before this, there is a need to reflect on key concepts of e-waste management to ensure a common understanding. The section below presents a review of these key concepts.

#### 2.1.1 Conceptual issues

This section reflects on terms regarded as critical to the study. These are e-waste and management. In this case, the section starts by reviewing the term management.

#### 2.1.2 Management

Taken in chronological order, of the contributors' insightful explanations, management is to "forecast, to plan, to organize, to command, to coordinate and control activities of others" (Henry Fayol, 1841-1925), the "art of getting things done through people" (Mary

P. Follett, 1868-1933), or, is a "multi-purpose organ that manages a business and manages managers and manages workers and work" (Peter Drucker, 1909-2005). To add to these voices, Hisson, (2011) refers to management as the process that includes strategic planning, setting, objectives, managing resources, deploying the human and financial assets needed to achieve objectives, and measuring results. Noteworthy is that all the definitions above map out the ideal or standard management function, but none of them delves into establishing the critical path for effective e-waste management. This is exactly what inspires this study, namely, to develop a model for effective electronic waste management for cities in developing countries such as Harare of Zimbabwe.

### 2.1.3 E-Waste

There exists a wealth of definitions contested by scholars that seek to enhance understanding of the e-waste phenomenon (Widmer et al., 2005; Oteng-Ababio, 2012; UNEP, 2013; Balde *et al.,* 2017; Mandevere, 2016; ILO, 2019). The absence of universal consensus on the definition has resulted in statistics with a magnitude of differences being presented in literature leading to loss of analytical validity and reliability of the presented data on the e-waste problem. Thus, e-waste as a concept is an elusive one (Balde *et al.,* 2015). Thus, e-waste as a concept radiates a variety of meanings for the different societies, cultures, and other diverse settings (Balde *et al.,* 2017).

Widmer, *et al.,* (2005) defines electronic waste as a generic term embracing various forms of electronic and electric equipment that have ceased to be of any value to their owners. Though the definition offers us an insight into what is e-waste, the definition does not classify the various forms of electronic and electric equipment. The classification is a bone of contention among various scholars (Oteng-Ababio, 2012; Sawhney, 2008; Sha and Shaik, 2008) and the definition of e-waste should be associated with the types of e-waste.

According to the OECD in Meltzer, (2014), e-waste is any appliance using an electric power supply that has reached its end of life. However, the problem with this definition is the classification of “appliances using electric power”. Some e-waste materials use battery power instead (Parajuly *et al.,* 2019). Thus, one may conclude that although the literature is awash with many definitions trying to conceptualise the phenomenon of e-waste, differing classifications have led to the proliferation of varied statistics about the phenomenon.

E-Waste is defined as any electrical and electronic products (household, or business) with circuitry, or electrical components with power or battery supply which have reached the end of their lifespan (StEP Initiative, 2014). The rigour of this definition is in its ability to negotiate the pitfalls of e-waste classification inherent in many definitions. For instance, Shah and Shaikh (2008) simply define e-waste as waste electrical and electronic equipment. In my view, Shah and Shaikh's definition fails to illuminate the phenomenon that has become known as e-waste.

However, what generally can be construed from the majority of definitions of e-waste present in current literature is the issue of contested e-waste classification. Such divergent thinking with no voice representing the society reflects confusion raising questions on whether some of the current studies on e-waste were focusing on the correct phenomenon.

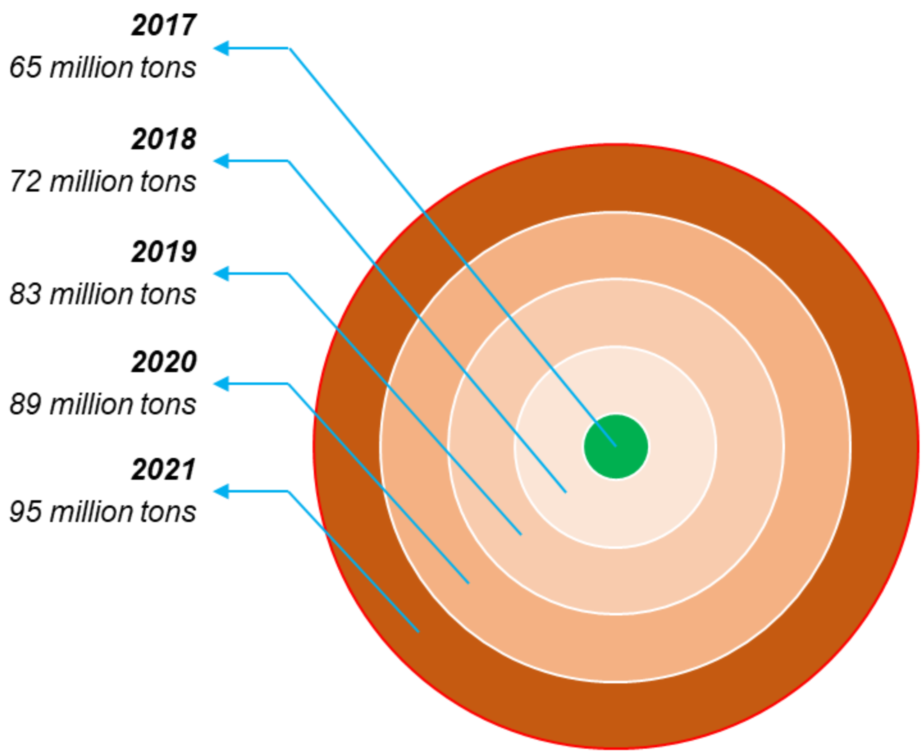
## 2.2 STATE OF GLOBAL E-WASTE

Advances in technological developments in contemporary times have brought with it comfort and ease. However, mirroring these comforts has been the onset of mammoth environmental challenges in the form of electronic waste around the globe. Once electronic and electrical products become obsolete or reach the end of their lifespan, they become waste. The accumulated electronic waste then consumes space, affects health and the environment through toxic substances, and the process of getting rid of these, leads to illegal dumping in under-developed and developing economies.

Electronics is today a vast industry due to technological advancements and the circulation of new and improved products into the market each day. So too is the electronic waste management industry. As consumers shift to new equipment, the resultant disposal of end-of-life electronics keeps multiplying. It is therefore an urgent necessity to find proper and scientific ways to dispose of the scrap electronics. The racing electronic market around the world is contributing to the growth of e-waste, three times that of urban waste (Cortes *et. al.,* 2016).

Due to the proliferation of electronic devices and accelerated technology advances an increasing amount of e-waste is created each year and Figure 2.1 below gives a skeletal view of the general increase in e-waste over years globally.

Figure 2.1: Global E-waste




Source: Adapted from Balde, *et al.,* (2017).

Hoornweg and Bhada-Tata, (2012) state that as the world hurtles towards its urban future, the amount of municipal solid waste, which is one of the most important by-products of an urban lifestyle is growing even faster than the rate of urbanization itself. This is illustrated by figures in Figure 2.1 above. E-waste is mainly a by-product of a consumer-based lifestyle that drives much of the world's economies and as such the electronic revolution and industry 4.0 are contributing significantly towards e-waste generation, hence the need to properly manage e-waste. However, though Figure 2.1 above has managed to present the current and projected e-waste generation levels, vital considerations for best practices in e-waste management remain elusive. Studies such as "E-waste in Zimbabwe and Zambia" by Gweme *et al.,* (2016) and "A Situational Analysis of Waste Management in Harare, Zimbabwe" by Tsigo and Togarepi (2012) have not focused on the establishment of vital considerations for the development of an effective e-waste management model.

Although developed countries have established regulatory programmes for the disposal of solid waste, developing counties have generally continued to use unsophisticated methods such as open dumps for waste disposal (Mandevere, 2016). With the usage of electrical and electronic equipment on the rise, the amount of electronic waste produced each day is growing exponentially around the globe. Figure 2.1 above shows the rate at which e-waste has and is being generated across the globe from 2016 to an estimated amount determined by current generation figures in the year 2021. The amount of e-waste is seen to be increasing with time yet so little is being done by the developing world to reduce and manage the generation of this form of waste. Since the world figures on e-waste are ballooning it means that cities in developing countries such as Harare should also be active to ensure the development of effective e-waste management mechanisms and avoid possible future environmental and health problems. An estimated generation of around 1.7 million tonnes of e-waste and a 7% growth rate is currently considered a significant challenge (ILO, 2014; Balde, 2015). This means that the rate at which e-waste is coming up, is very high and requires attention from all players across the globe involved. Despite such projected figures for e-waste growth, very little has been done in terms of developing vital considerations to effectively manage the e-waste problem.

Generally, there has been different views on what constitutes e-waste (Widmer et al., 2005; Oteng-Ababio, 2012; UNEP, 2013; Balde *et al.,* 2017; Mandevere, 2019; ILO, 2019; Maringe *et al.,* 2015). However, items such as computers, televisions, stereos, fax machines, and other electronic products nearing the end of their useful life are generally considered electronic waste or e-waste (ESDO, Bangladesh 2010). These materials have contributed highly to the increase in e-waste across the globe. The increase in electronic scrap has led to the growth of massive dumps often undesignated in cities in developing economies (Gaidajis *et al.,* 2010). The danger of such is that e-waste mainly contains materials like glass, plastics, and metals (Ari, 2016). The hazardous and toxic contents emitted from e-waste in landfills leach to groundwater and transfers to water bodies and land resources (Needhidasan *et al.,* 2014) polluting them. These toxins include elements like chromium, cadmium, mercury, lead, and others. (Needhidasan *et al.,* 2014) which could be extremely dangerous to health and the environment (Pinto, 2008), especially during treatment and recycling (Sinha, 2002). As per various studies, it was observed that toxic heavy metals released from discarded e-waste cause serious health impacts to the nervous, reproductive, and blood circulatory system (Flora *et al.,* 2012), cancers, and neurological disorders (Bhutta *et al.,* 2011) skin damage, vertigo, nausea, chronic gastritis, etc. (Monika and Kishore, 2010). However, despite such knowledge, very little has been done to establish the vital considerations for best practices in e-waste management.

It is estimated that global e-waste generation is growing by about 50 million tonnes per year (Oteng-Ababio, 2012). Globally, in the decade between 1994 and 2003 about 500 million personal computers containing approximately 718 000 tonnes of lead, 1 363 tonnes of cadmium, and 287 tonnes of mercury, reached their end-of-life (Smith *et al.,* 2006). This means society is creating its own toxic footprints and this is why Oteng-Ababio, (2012) indicated that the same hyper-technology that is hailed as a "crucial vector" for future societal development has a not-so-modern downside to it which is electronic waste. These figures are a clear testimony that electronic waste is a threat to humanity and the environment. The threat posed by e-waste has been most pronounced in cities in developing countries. This then means there is a need to critically look at e-waste management regime in these countries and assess whether it is both effective and sustainable. The mere fact that e-waste contains more than 1000 different substances, most of which are hazardous, means it's a dangerous form of waste that requires proper and modern management mechanisms. However, despite such apparent threats posed by e-waste, current research thrusts seem to have missed the mark in terms of establishing the vital considerations for effective e-waste management.

In most cities of the developing world, there is a lack of proper environmental management facilities, such as landfills (Mandevere, 2016). This situation makes the management of e-waste complex, considering that it involves heavy metals that require not only technology but also financial abilities to handle this problem. The domestication of the Basel and Bamako Convention of 1989 and 1994, respectively, has remained utopian for most developing countries (Tevera *et al.,* 2006). The proliferation of electronic waste in most cities in developing countries makes the road to waste management very complicated. The disposal of the associated waste at the end of their life-cycle is critical, as these contain life-threatening substances, such as lead, cadmium, iron, zinc, and other dangerous substances, which if not properly handled can seriously and negatively impact the population and make the environment completely barren (Namias, 2013).

E-waste has become a subject of growing environmental concern in both developed and developing countries due to the large volumes of e-waste in need of disposal. According to Zerbock, (2003) the management of waste has become so complicated that it defeats the available options. For instance, Ghana has become so overwhelmed by e-waste disposal, so much so that its capital Accra, has been dubbed "the e-waste capital of Africa" (Meltzer, 2014). Electronic waste management is a formidable challenge in areas where the population is increasing and there is a corresponding demand for electrical goods. With Harare's current population estimated at 4,141.849, it can be surmised that the city's population will require gadgets that will ultimately become e-waste in the short to medium term. As such, this necessitated an assessment of e-waste management to establish the requisite elements of a model for effective e-waste management. Although studies have established states of global e-waste in most countries across the globe (Balde *et al.,* 2015; 2017; Sitaramaiah *et al.,* 2014; Ongondo *et al.,* 2011; Waste classification (ILO, 2007; Oteng-Ababio, 2012;; Mandevere, 2016; Jaishankak *et al.,* 2014; Townsen, 2011; Rao, 2014; Rayputje, 2013; Panda, 2013;

Zhang *et al.,* 2012; Mahurpawar, 2015), very few have interrogated the vital considerations for effective e-waste management.

The United Nations Environmental Programme (UNEP, 2008) estimated an average of more than 6, 8 kg of e-waste produced per every living person in the year 2012. It was also noted that of the 7 billion global populations, at least 6 billion have mobile phones (UNEP, 2008). These will eventually add to the pool of electronic waste. In 2012 China reportedly generated 11.1 million tonnes of e-waste and the United States (US) produced 10 million tonnes (Namias, 2013). These figures are too big and a threat, especially to developing countries like Zimbabwe, because the current e-waste regulations allow for the exportation of e-waste from the developed countries to developing countries under the guise of donations and recycling (Namias, 2013). This is against a backdrop of e-waste management incapacitation for most of these developing countries. The result has been growing e-waste levels leading to both health and environmental problems in most developing countries.

A 2012 UNEP report projected that by 2017, global e-waste would have increased by a further 33% from 49.7 million to 65.4 million tonnes per annum. It was then also estimated that e-waste from India would increase 18-fold by 2020. The increase in e-waste is a result of the frequent and sometimes unnecessary purchase of Electrical and Electronic Equipment (EEE) such as new cell phone models being released at regular intervals (Sitaramaiah, *et al.,* 2014). It has also been worsened by the reduction in the life span of electronic gadgets. Gabaitiri *et al.*, (2012) for example, report that the average computer lifespan has dropped in recent years by 50% from 4 to 2 years. According to the UNDP (2008), the reason for this is because manufacturers would like to have customers at regular intervals and make a steady and consistent profit. The desire for profit and electronic goods among producers and consumers respectively has resulted in e-waste management challenges. It is against this background that this study sought to assess e-waste management in Harare, Zimbabwe to establish vital considerations for an effective e-waste management model.

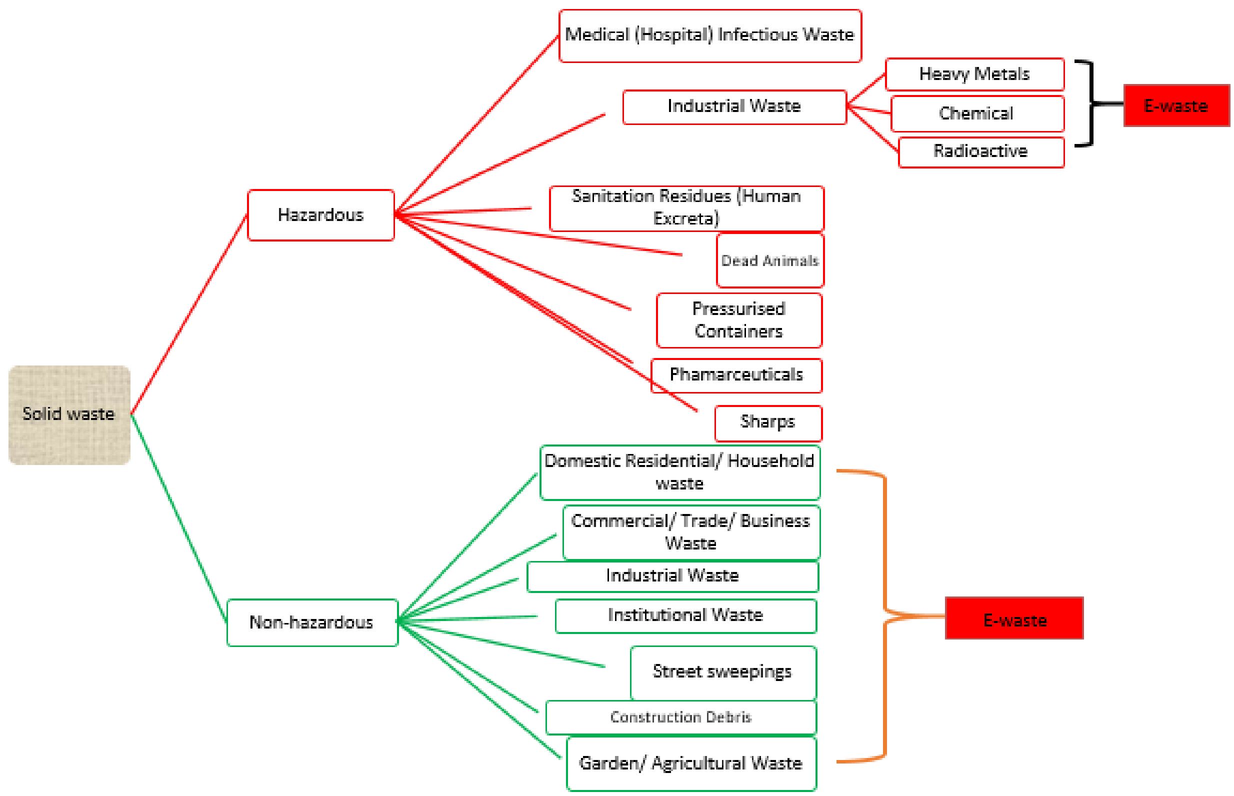
Electronic pollution has detrimental effects on both human health and the biosphere (Shah and Shaikh, 2008). The disposal of Personal Computers (PCs) from 1991 to 2003 resulted in 718,000 tons of lead, 287 tonnes of mercury, and 1,363 tonnes of cadmium being placed in landfills in the United States. If unmanaged properly, the mercury, chromium, lead and brominated flame retardants are likely to cause the most adverse health effects in humans (Shah and Shaikh, 2008). According to Namias, (2013), 50 million tonnes of e-waste was disposed of in 2009 and 72 million tonnes were expected to be disposed of in 2014. These figures show that e-waste is a fast-growing problem requiring imminent measures if the sustainable development concept is to be realized by developing countries and their cities like Harare of Zimbabwe. However, despite an understanding of the state of global e-waste, the issue of establishing vital considerations for effective e-waste management seems to have escaped the academic radar. To firmly understand e-waste management, there is a need to understand how waste is classified.

## 2.3 WASTE CLASSIFICATION

Waste takes various forms and critical are the two main classes of waste which are hazardous and non-hazardous waste. It is also pertinent to note that these two major forms of waste are dumped at the dumpsites in most cities in developing countries are irrespective of their origin, nature, and potential negative or positive impact on the environment and human health in general (Mandevere, 2019). This is basically because most developing countries do not have proper landfills and waste separation is on the other hand a dream as these countries do not have financial resources to invest in waste management. The technology that comes with e-waste management is too expensive to acquire and employ for developing countries.

Non-hazardous waste is that with no effect on human health as well as the environment. Hazardous waste is that which causes direct or indirect problems to both the environment and human health in general. Focus in this particular case is on electronic waste in cities in developing countries like Harare. Although the diagram presented in Figure 2.2 above has been able to present the classification of waste, it fails to take note of e-waste as an independent waste form, as it gives a general picture of hazardous waste and it also fails to account for vital considerations for effective e-waste management. Figure 2.2 below shows how waste is classified.

Figure 2.2: Waste Classification




Source: Adopted from ILO, (2007).

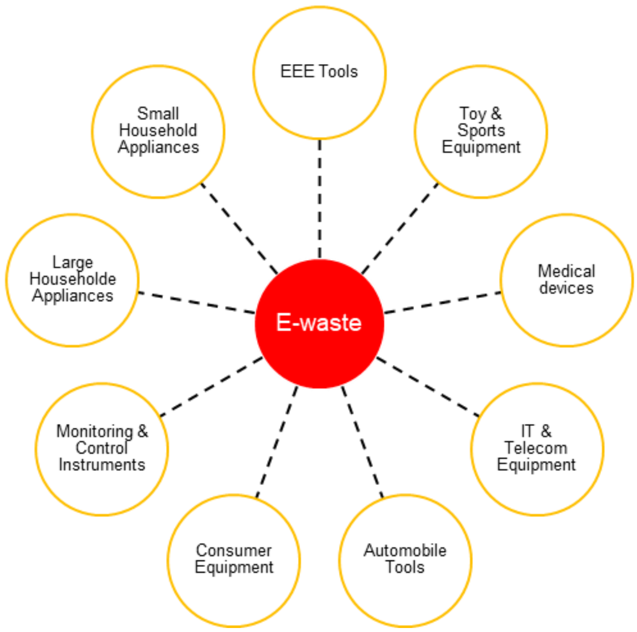
The irony is e-waste management is that it is a budding challenge as well as a business opportunity of tremendous significance to society. According to Oteng-Ababio, (2012) over 60 % of e-waste is iron, copper, aluminium, gold, and other metals and plastics account for about 30% with hazardous pollutants constituting about 2.7 %. This shows that there are two sides to the coin of e-waste. Recycling may salvage these important minerals and if improperly disposed becomes a risk both to the environment and human health. When looking from this perspective of proceeds, then it becomes imperative to audit existing frameworks for e-waste management in Harare, Zimbabwe to establish vital considerations for an effective e-waste management model.

ILO (2007) classifies waste as shown in Figure 2.2 above. The classification does not specifically indicate e-waste as a form of hazardous waste. It must however be noted that e-waste is a common denominator as the kind is an all-rounder found in medical waste as medical devices, industrial waste, household, commercial waste, and institutional. The reason why it is common in all aspect is that the electronic revolution and industry 4.0 has revolutionised all sectors of the economy bringing about the use of electrical and electronic goods in every aspect of economic development. This means the birth of increased e-waste as products of these two are on the increase with also poor electronic products flooding the market with a very small life span which see the e-waste and other forms of waste join the grave faster than expected.

Solid waste is categorised into two main types, which are hazardous and non-hazardous (ILO, 2007). Critical to this study is the Hazardous waste in the form of electronic waste. This kind of waste is generated from industrial, institutional, commercial, and households. There is hazardous waste in what seemingly looks like a non-hazardous waste especially if looked at without critically looking at other issues. This means that e-waste, therefore, becomes a dominant kind of waste as each part of the development and human habitation is witnessing the birth of the electronic revolution. Every part of waste management may include a computer being used for information capturing and with time it will turn into e-waste and therefore waste management that does not look at e-waste is failing to address critical matters of waste management.

Rajput (2013) postulated a way to classify e-waste differently from the one proposed by ILO (2007). The scholar categorised e-waste into: [1] Automatic dispensers, [2] Large household appliances, [3] Small household appliances [4] IT and telecommunication [5] Consumer equipment [6] Lighting equipment [7] Toys, leisure, and sports equipment [8] Medical devices [9] Monitoring and control instruments, and [10] Electrical and electronic tools. This classification is based on the size of the electronic device or gadget involved, it does not show the levels of the dangers of each class of e-waste. It however goes a long way in trying to classify e-waste. This form of classification is shown in Figure 2.3 below.

Figure 2.3: Types of E-Waste

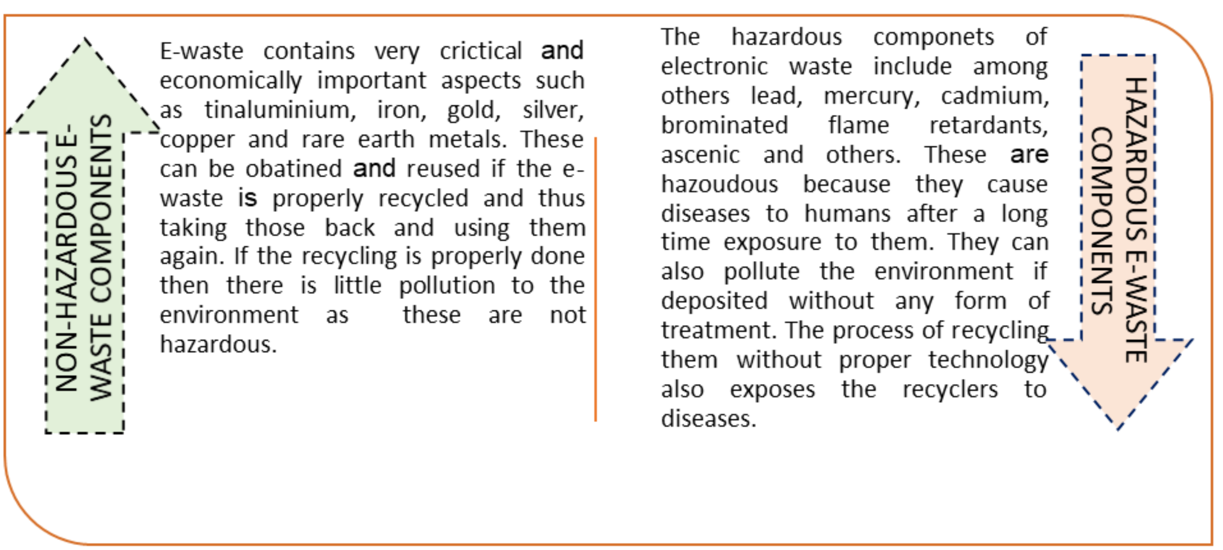



Source: Rajput, (2013).

Figure 2.3 above on e-waste topology assists in the classification of e-waste. The various forms of e-waste show that e-waste emanates from various areas of development in society. Every part of development and society generates e-waste in one way or the other and thus, there is a need to treat e-waste as a special form of waste with the potential to cause human and environmental problems. Though Figure 2.3 above helps us understand how e-waste is classified and there is a need to search for vital considerations for effective e-waste management in their various forms indicated above.

There are some components of e-waste that are beneficial to society and these need to be extracted from the waste through recycling and some extractive metallurgy. The extraction of such and the management of the hazardous waste is however the most difficult aspect for the developing countries such as Zimbabwe and their cities such as Harare because they lack technology, human expertise, and the general knowledge on how to manage e-waste. Furthermore, valuation of e-waste management in most cases rides the back seat as there is a running general feeling that there are other critical aspects of development that are more important for the cities than e-waste management. According to Gweme, *et al.,* (2016) apart from the e-waste produced by their own consumption, African countries are on the receiving end and this is further complicated by the fact that there is no inventory to help assess the extent of e-waste. Despite this lack of statistics on e-waste, it is known that there are hazardous and non-hazardous sides to this form of waste, and thus there are two sides of the same coin. Therefore, the two e-waste components as shown in Figure 2.4 below. These aspects are the basis on which e-waste management drinks from as its management entails handling the hazardous aspect of it properly while maximising the benefits of the non-hazardous components thus bringing about proper e-waste management.

Figure 2.4: Hazardous and Non-hazardous E-waste




Source: Primary Data, (2019).

The management of e-waste is difficult in most developing countries because of its hazardous components and the general nature of poor e-waste handling in developing countries (Williams, 2002). The recycling of e-waste also requires critical technology to process, yet this is not found in developing countries as they are struggling to manage any form of waste, even that which they can turn to energy and benefit them. Harare, Zimbabwe does not even have a proper landfill, and as such proper e-waste management is difficult to achieve. Therefore, e-waste management is a complex aspect that requires serious attention especially on the hazardous components of e-waste, most importantly heavy metals.

The management of e-waste is difficult in most developing countries because most of them do not have the financial and critical technology to process e-waste and the general inadequacy of e-waste management frameworks (Williams, 2002). The management of e-waste is complicated by the hazardous components as these require critical technology to process. Such advanced technologies to manage hazardous e-wastes are hardly found in most developing countries. These challenges pose complications in the handling of e-waste. In most cases, has resulted in increased environmental pollution and disease outbreaks due to contaminated drinking water sources.

Another way of classifying waste is the use of size. The categorization of electronic waste is a product of the origin and size of the electronic equipment from which the waste is generated. The various e-waste types are listed in Table 2.1 below along with the examples for each. Oteng-Ababio (2012) presents another unique way of classifying wastes. The scholar classifies EEE as either 'white goods' which are household appliances such as refrigerators and dishwashing machines, 'brown goods' which are like television and cameras, and the 'grey goods' such as printers and scanners. Usually, grey goods are more complex to recycle due to their toxic composition. This categorisation is difficult as Harare lacks the expertise to do so. As such, the management is also difficult as it starts with categorisation and classification for easy treatment and disposal. The ability to determine the class of a given form of e-waste is critical to its management. yet this is the missing link in the management of e-waste in most developing cities as they do not have the skills to identify such most developing cities are just realising it now that e-waste is a dangerous form of waste that require serious handling and as such are adjusting although gradually compared to the rate at which the e-waste is mushrooming their cities. Below is Table 2.1 showing e-waste classes and examples of such.

Table 2-1: Examples of E-waste Appliances and their Classes

| | **E-WASTE CLASSES** | **TYPES OF APPLIANCES** |
|---|---|---|
| **1** | Large Household Appliances | Refrigerators, Freezers, Washing machines, Electric hot plates, Microwaves, and others |
| **2** | Automatic dispensers | Automatic dispensers of hot drinks, hot or cold bottles or cans, automatic money dispensers |
| **3** | Monitoring and Control Instruments | Smoke detectors, Heating regulators, Thermostats |
| **4** | Consumer Equipment | Radio and Television sets, Audio amplifiers, Musical instrument |
| **5** | Lighting equipment | Compact and straight fluorescent lamps, low-pressure sodium lamps |
| **6** | Electronic and Electronic tools | Drills, sewing machines, tools for welding, soldering, mowing tools |
| **7** | Toys, leisure, and sports equipment | Electric cars and trains, sports equipment with electronic components |
| **8** | Medical devices | Freezers, Nuclear medicine, Dialysis, Cardiology, Radiotherapy equipment |
| **9** | Small household appliances | Vacuum cleaners, Toasters, Juice maker, hair cutting, hair drying, tooth brushing, and others |
| **10** | Information Technology (IT) and telecommunication equipment. | Printers, Laptop and computer Central Processing Unit (CPU), Telephone, Telex, batteries, |

Source: Adapted from Sawhney, (2008).

Although Table 2.1 above has clearly outlined how e-waste can be classified, it remains outside the scope of many studies on how e-waste can effectively be managed. This status quo comes despite e-waste becoming a global problem. To fully comprehend the magnitude of the e-waste problem, the section below presents e-waste generation global figures estimated to 2012.

## 2.4 E-WASTE GENERATION GLOBAL FIGURES ESTIMATED TO 2021

The world has been reduced to a mere village due to globalization as well as the electronic revolution that has made communication easier. The e-waste being produced in the world currently is alarming and seems difficult to manage for developing countries like Zimbabwe. The world estimates that e-waste is exponentially growing and Figure 2.4 below shows the growth from 2016 to 2021. The fact is that the increasing market penetration in the developing countries, 'replacement market' in the developed countries and 'high obsolescence rate make e-waste one of the fastest-growing waste streams. The problem is that e-waste pollution attacks both human health and the biosphere. Intense e-waste pollution may cause diseases, sterilize the entire population, and may produce genetic defects in future generations.

Balde *et al.,* (2017) indicated that by 2016 the world had generated 44, 7 million metric tonnes of e-waste, and only 20% was recycled through appropriate channels. E-waste is the fastest-growing type of hazardous waste globally (Puja Sawhnay, 2008) this is because in most if not all developing countries it is often cheaper to buy a new device than to repair it hence the rate of disposal has been on the rise (Puja Sawhnay, 2008). The greatest challenge is that it is very difficult for developing countries to turn waste into resources or appropriately dispose of it. According to Kuper and Hojsik, (2008) as the global market for electronic goods expands and the lifespan of many of these products gets shorter, there has been a rapid growth in electronic waste.

Sending old electronic equipment to developing countries is often hailed as “bridging the digital divide”, but all too often this simply means dumping useless equipment on the poor (Oteng-Ababio, 2012). One estimate suggests that 25-75 % of second-hand goods imported to Africa cannot be reused (Oteng-Ababio, 2012). The developed countries bring electronic equipment to the developing countries ostensibly to bridge the digital gap, yet they are creating a digital dump (United Nations Environmental Management Group, UNEMG, 2017). According to the US addressing the full life-cycle of electrical and electronic equipment is central to the 2030 development agenda. About 66% of the world population is covered by e-waste legislation, more efforts must be made to enforce, implement and encourage more countries to develop e-waste policies as most people are living at the mercy of nature.

Since most electronic equipment is often cheaper to buy a new device than to repair it, the rate of disposal has been on the rise. Thus, more obsolete equipment is thrown away and the amount of e-waste has significantly increased posing a serious problem. Thus, WEEE being a societal problem demands a social solution where all stakeholders contribute in line with their positive influence on the solutions side, producers, retailers, and consumers all have a role to play in the management of WEEE (Otsuka *et al.,* 2012). In Japan, they use the word 'Mottainai' which explains the treasuring and using of electrical and electronic goods as long as possible; this motivates the reuse of products, recycling and thus reducing waste.

Managing normal waste from households in developing countries already appears to be an insurmountable task. It is, therefore, more complex if the e-waste invasion from developed countries finds an easy entry into the developing countries all in the name of trade. The resultant waste is posing a serious challenge in disposal and recycling and creating ugly solid waste management scenes in most developing societies because most developing countries have neither adequate technologies nor adequate facilities for handling e-waste properly and in an environmentally sound manner, thus, solid waste to include e-waste becomes the most visible and pernicious by-products of a resource-intensive, consumer-based economic lifestyle.

Although this section has managed to bring to the fore the magnitude of the problem posed by e-waste, a close analysis of the existing literature indicates that critical considerations for effective e-waste management remain under-theorized especially for cities in developing countries. To completely understand the importance of having vital elements to consider for effective e-waste management, the section below presents e-waste generation per continent.

## 2.5 E-WASTE GENERATION PER CONTINENT

It would appear that, generally, the rate of e-waste generation across the globe is more prevalent in developed than developing countries. This is attested to Table 2.2 below which shows the amount of e-waste generation per individual per continent.

Table 2-2: E-Waste generated per inhabitant per continent

| ***CONTINENT*** | ***E-WASTE GENERATED PER INHABITANT IN THE CONTINENT*** |
|---:|---:|
| Africa | 1.9 Kg/inhabitant |
| America | 11.6 Kg/inhabitant |
| Asia | 4.2 Kg /inhabitant |
| Europe | 16.6 Kg/inhabitant |
| Oceania | 17.3 Kg/inhabitant |

Source: ILO, (2019).

Africa and Asia have the least generation levels of e-waste abilities as compared to America and Europe. This means that developing countries have the least e-waste yet they cannot handle the e-waste, the result is more pollution. Developed countries are also are now donating second-hand goods to them and thus complicating their situation for developing countries as they lack the technology to recycle e-waste. The world is showing that the greatest number of inhabitants with large volumes of e-waste related aspects is the developed world and as it stands Africa has the list in Table 2.2 above. This explains that Africa cannot pollute its environment with its own generated e-waste. However, the irony is that most of the e-waste generated in developed countries ends up finding its way to Africa, hence the need to develop a model for effective e-waste management.

The relationship between the developing and developed world is the greatest problem and the exponential growth of e-waste in developing countries is a product of the relationship between the two. The donations and imports of electrical and electronic goods are mistaken for development yet it is a problem because African countries greatly lack the capacity and technology to handle, recycle and reuse these electronic wastes and their hazardous nature. A greater part of e-waste in developing nations is not collected and the treatment is skeletal and rudimental and not in an environmentally sound manner.

The intrinsic material value of global e-waste was estimated to be 48 billion Euros as in 2014, the material value is dominated by Gold, Copper, and Plastics. It must however be noted that the importation of second-hand electrical and electronic goods is increased and has contributed to more e-waste to the already burdened developing countries. This is why to the developed countries it results in urban mining and benefits while to the developing countries it is environmental pollution and public health problems. The other problem is that most of the developing world does not realize that most health problems are associated with heavy metals, most of which come from e-waste.

It must however be noted that a better understanding and more data on e-waste will help and contribute to the achievement of several goals of the 2030 Agenda for Sustainable Development. This is linked to goals 3, 6, and 11 which are good health and well-being, clean water and sanitation, and Sustainable Cities, respectively. Such a better understanding would lead to the development of a model for effective e-waste management which is currently lacking in the available literature. Current best practices on e-waste management in literature have been developed for developed countries. There remains a need to develop tailor-made models for effective e-waste management for cities in developing countries. To fully understanding the scourge posed by e-waste, there is the need to have an appreciation of the sources of e-waste around the globe.

## 2.6 SOURCES OF E-WASTE ACROSS THE GLOBE

The world is faced with serious e-waste management problems. This is especially so in developing countries where the importation of substandard goods with increasingly shorter life spans subsequently leads to the improper disposal of the electronic and electrical products into the environment as e-waste once they have expired. However, while such varied e-waste is increasing daily, very little to nothing is being implemented to ensure and manage its proper disposal. In the same vein, while the ability to measure e-waste is a critical aspect in its management, more than 80% of developing countries are unable to do so (Oteng-Ababio, 2012). Without knowledge of the quantities, it is not possible to put in place management strategies. The ownership of multiple electronic and electrical devices by one individual, as well as the electrification of previously non-electrical equipment to increase production, has also added to e-waste and concerns around its managed disposal. This has been compounded by the short replacement cycle of most electrical and electronic goods on the market which rapidly become e-waste faster than the gradual process of managing e-waste can accommodate.

The gap in legislation framework for e-waste management and regulation, coupled with low levels of awareness, and high demand for second-hand electronic goods contribute to e-waste. The worst problem is when e-waste is recycled rudimentary and skeletal methods are employed and thus creating health problems for those involved. According to UNEP, (2013) open dumping remains the prevalent waste disposal method in most low-income counties like Zimbabwe. This is because industrialization, urbanization, population increase and economic development are all contributing to the cup of e-waste.

The African continent hosts the least number of direct manufactures of EEE, yet it accounts for a significant portion of the global e-waste generation of about 2.2 million tonnes annual output (Blade et al., 2014). The challenge for e-waste management in these developing countries is inadequate legislation, poor awareness and a general reluctance by governments of these countries to handle e-waste. The electronic industry is the world's largest and fastest-growing manufacturing industry (Radha, 2002). This is true in developed countries and hence the imbalance between the two in terms of e-waste generation and disposal.

Population distribution is uneven, and the greatest growth has taken place in the countries least capable of sustaining increased population, such as developing countries whose e-waste management is very poor. Tevera, *et al.,* (2003) argue that an increase in population equals increased generation of waste. This was also discovered by Redelinjihiys, (2010) cited in Mandevere, (2016) who used the formula:

**I = PAT**

In a bid to give an analytical picture on the influence and role of population size, affluence and technology in environmental degradation and pollution, where:

**I** = Environmental Impact,

**P** = Population size,

**A** = Affluence,

**T** = Technology.

The effects of e-waste which is rapidly growing due to population growth would eventually contaminate human beings as they are transmitted through the food chain and ultimately somatic and genetic changes could take place on humanity (Nhete, 2006). Therefore, the problem of e-waste in developing countries is a product of very large urban populations whose lives have modernised and demand the use of electronic goods. Chadians, (2006) indicated that there is a lack of technology in Zimbabwe for waste management and with e-waste alongside the situation will eventually blow out of hand unless measures are taken now to ensure proper e-waste management while the levels are still manageable.

There are many landfills in first world countries like America, Switzerland, Canada and England (Curran, *et al.,* 2007; UNEP, 2008), this is however the opposite to developing counties in which dumping is common. The dumping of e-waste means adding heavy metals to the environment and with a bigger population dumping e-waste, the levels of pollution will be very high and thus threatening the abiotic and biotic environment.

In dumpsites, there are no methodology and precautions to control leachate (Dariusz, 2003). This means that underground water is polluted, and this also affects aquatic and land organisms in the soil as well as plants and vegetation. This, therefore, means that the management of e-waste is very critical hence the need to closely look critically at Zimbabwean e-waste management with special reference to Harare her capital city. In most developing countries, almost 100 per cent of generated waste goes to dumpsites or is illegally dumped including e-waste (Allan, 2001). This is unlike in developed countries where e-waste is recycled properly and even benefit the country. Allan, (2001) indicated that these dumpsites in developing countries are a source of groundwater pollution and affects the environment and its inhabitants.

Dangerous substances such as heavy metals may leach out of these dumps and pollute underground water which in turn might pollute surface water sources (UN-Habitat, 2010). This would be harmful to living organism and plants around them.

E-waste is an environmental problem that has not received much attention in Sub-Saharan Africa (Ezeah, 2010). The lack of e-waste management is reportedly due to developing countries inability to fund its management (Tevera, *et al.,* 2003). Consequently, it is Williams' (2002) view that e-waste will continue to increase to both the detriment of the environment and human health if no immediate action is taken to reduce both e-waste and its effects.

However, understanding the sources of e-waste alone becomes irreverent in the face of the growing environmental and health hazards posed by the growing problem of e-waste. Current studies have failed to prescribe a model for effective e-waste management for cities in developing countries. To fully understand the problems of e-waste, the section below presents the global e-waste issues.

## 2.7 GLOBAL E-WASTE ISSUES

The development process in different areas of the world is varied and does not happen identically as this is not a homogeneous process. The heterogeneous nature of development has resulted in a world that is divided into developed, developing and under-developing countries. To date, various development revolutions have been born and these include the green, industrial and currently the electronic revolution. The electronic revolution has revolutionised the production of e-waste in various forms. Due to changes in production, household structures and lifestyles, sub-urbanization occurred in most urban regions; whether they are economically prospering or not. Blade *et al.,* (2015) observed that Africa compared to Asia, the Americas and Europe generated the least quantity of e-waste estimated at 1.9 million tonnes in 2014.

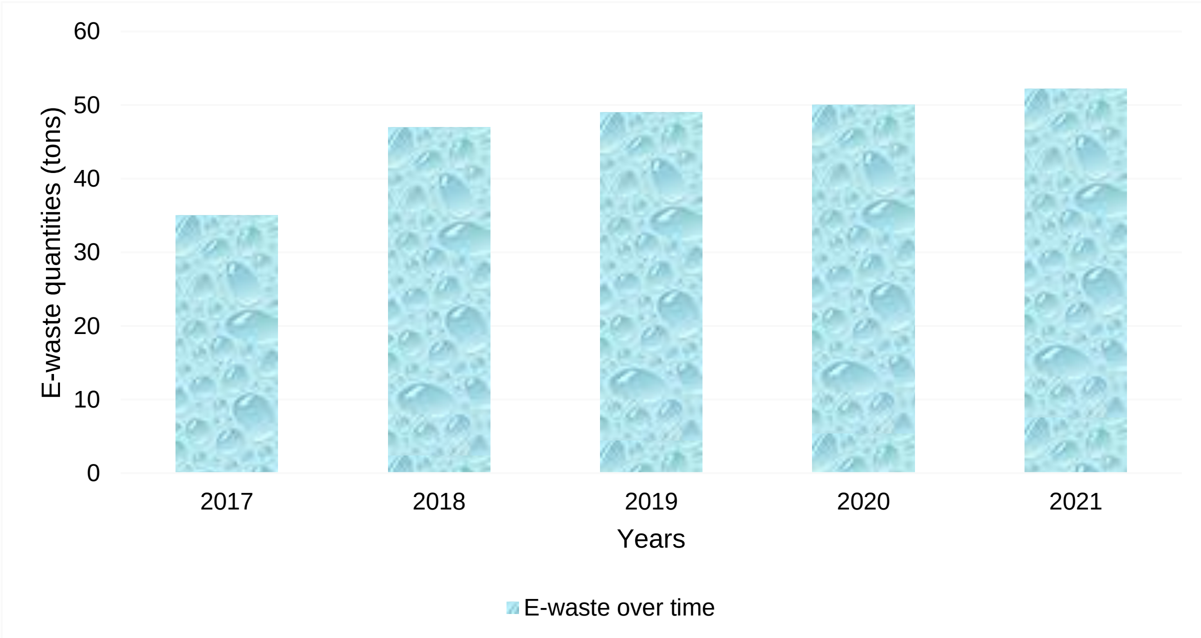
The e-waste generation takes various forms and effects as the level of development of a country determines the ability of a country to manage this form of waste with the best practices in developed countries and worst in developing countries. According to Balde *et al.,* (2017) by 2016, the world generated 44.7 million metric tonnes of e-waste and only 20 % was recycled properly. This means that e-waste is a threat to humanity and the environment the world over.

This complicates the management of e-waste as the basis of its best management lies in knowing what is being produced as this will generate the panacea to handling the problems that come along with e-waste.

The world currently accounts for 7.2 billion mobile phone subscriptions (Balde *et al.,* 2017). This along with other unaccounted devices plus the multiple ownership of devices bring a lot of potential e-waste problems, mostly in developing countries whose population has adopted a throw-away culture to e-waste management. In other cases, the buying of a new electrical device is socially a symbol of social recognition.

The estimated trends for world e-waste generation shows that a lot of planning has to be done as the increase in e-waste will result in more pollution to the environment as well as human health problems. Figure 2.5 below shows estimates of what is anticipated by the global e-waste monitor from now up until 2021. The global e-waste monitor has a long way to go as evidence on the ground points to false statistics because most developing countries like Zimbabwe do not have statistics on e-waste. This is regarded as a non-issue because developing countries feel waste issues are not topical to them since it is developmental issues that are key to their economies. What they fail to realise is that the generation of e-waste and failing to manage it will result in major environmental and health effects which again will impact negatively on what most of the developing countries are fighting to achieve now, which is development. Development is nothing if the environment is not clean as it will negatively affect it.

Figure 2.5: Estimated E-waste Trends over Time

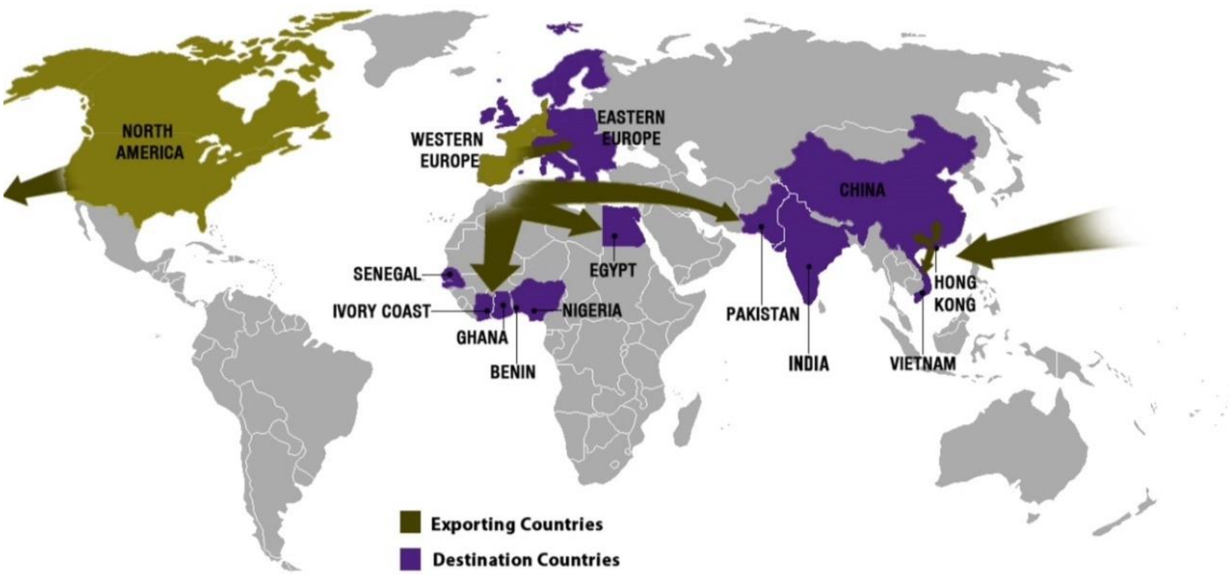



Source: Balde, *et al.,* (2017).

The estimates show that e-waste generation increased from 2017 upwards to 2021 and hence the need for mechanisms to get correct statistics of the e-waste being generated. It is also important to note that it is not only about statistics but also legislation to deal with e-waste. The Basel Convention seeks to control the transboundary movement of hazardous waste and its disposal. However, while around 186 countries in the world have signed this convention the rest are yet to ratify. This complicates the management of e-waste the world over. A fact that is further compounded by developing countries fledgling or non-existent e-waste management amenities and skills. Balde *et al.,* (2016) indicated that up to 60 elements from the periodic table are found in complex electronics and many of them are technically recoverable, though there are economic limits set by the market. Although the bar graph (Figure 2.5) gives insight into the e-waste trends, what is evident is that a general appreciation of the problem alone is not important. There is a need to establish vital considerations for effective management of the growing e-waste problem.

As the world attempts to deal with e-waste, there are critical challenges that need to be addressed. These have to do with the way electrical and electronic goods are exported and imported by different countries across the globe. Figure 2.6 below gives an overview of the movement of electronic waste from one continent to another.

Figure 2.6: Global Legal and Illegal E-Waste Movement




Source: Greenpeace, Basel Action Network (2002)

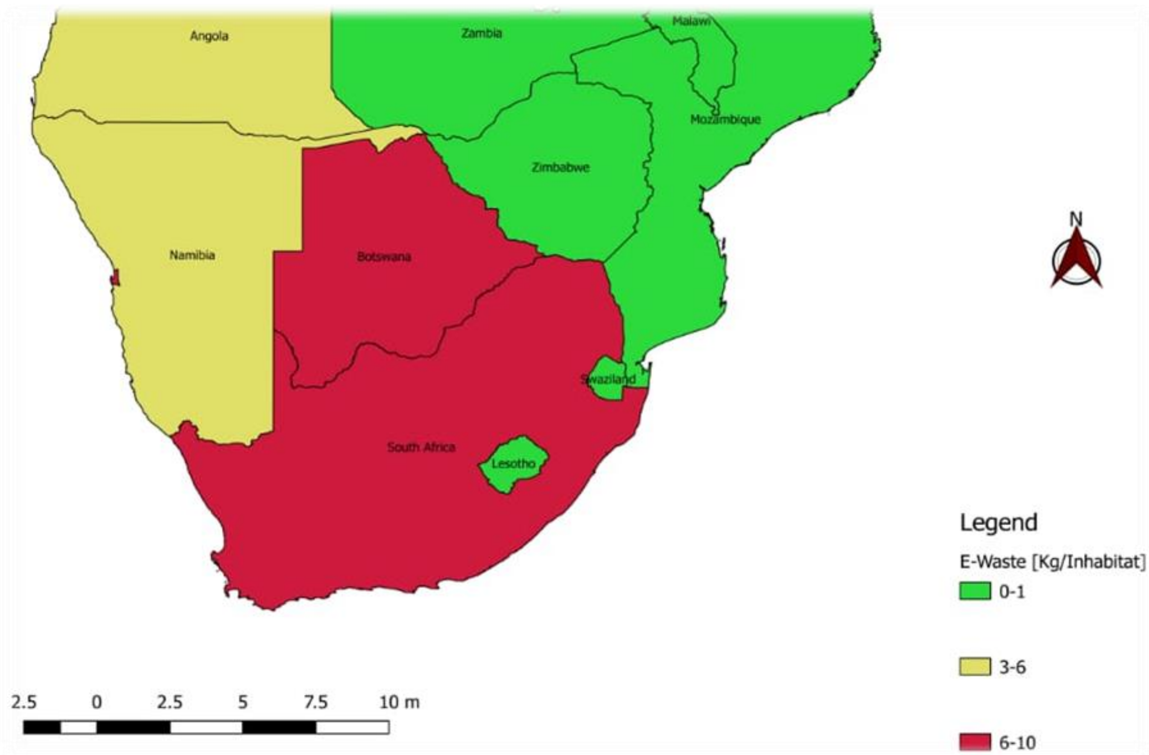
There are however clear movement routes within continents and hence the need to establish such routes as these goes a long way in coming up with management mechanisms for e-waste. According to the ILO, (2012) and Lu *et al.,* (2015) WEE trade patterns are still difficult to assess especially in LMICs. The information presented in Figure 2.6 above shows that there are known sources and destination of e-waste across the world but also critical are suspected destination to which Africa is a victim and thus e-waste becomes a challenge. Zimbabwe is not among the suspected e-waste destination, but chances are that e-waste can also be broadcasted from the suspected destination to Zimbabwe. Electronic moves from continent to continent (inter-continental e-waste movement), within continents it moves from country to country (intra-continental e-waste movement) and within a country, e-waste moves from urban centre to urban centre (inter-urban e-waste movement). This can go down to movements within households and organizations thus complicating waste management if no proper legal instruments are in place to monitor such movements. The section below gives country-specific information on the ratification of the Basel Convention and the movement of e-waste.

## 2.8 SOUTHERN AFRICA

Most African countries ratified the Basel Convention. However, the majority do not appear to have home-grown legislation derived from the Convention. This is attributed to the fact that they are unaware of the effects of e-waste on both the environment and human life as such they see no need to manage e-waste by way of law. African countries such as Madagascar [2015], Kenya [2016] and Ghana [2016] in different years have formally passed draft bills on e-waste into law. South Africa, Zambia, Cameroon and Nigeria are still moulding their e-waste legislation in line with the Basel Convention. Other than South Africa and Botswana, as shown in Figure 2.7 below, most Southern African countries generally have a very low level of e-waste generation per inhabitant.

The e-waste generated per inhabitant in the Southern African Development Community (SADC) shows that countries like South Africa and Botswana are producing 10+ kg per inhabitant and these seem to dominate the generation of e-waste in the SADC with South Africa as the major producer of electrical and electronic goods in the region and supplying the rest of the region. Namibia and Lesotho follow at a much lower generation rate since they have about 3 to 6 kg per inhabitant. These statistics may vary from what is presented in Figure 2.7 below, but it must not be ruled out that some countries within the region do not have up to date statistics hence a distorted picture of e-waste in the SADC. The only country in the SADC with better e-waste management statistics is South Africa. The rest of the countries do not have proper figures, if any. This goes to say a lot still has to be done in the SADC regarding e-waste management. The sustainable goals for society are preaching of clean cities and clean water but these threatened by e-waste as its management mechanisms in Zimbabwe and other countries are yet to be witnessed. It seems currently the city authorities are still wondering how to deal with e-waste. The pool of e-waste in SADC is not known because some of it is still kept indoors and people do not understand e-waste issues, especially where the people are not educated about it.

Figure 2.7: E-Waste per Inhabitant in Southern Africa




Source: Adapted from Balde, *et al.,* (2017).

Zimbabwe, Mozambique and Zambia are generating around 0 to 1 kg per inhabitant as shown in Figure 2.6. This means that while the generated waste per inhabitant in Zimbabwe, seems small compared to other countries within the region and the developed countries, it is critical to ensure that it is well understood and managed before it matures into a complicated and formidable problem. However, an understanding of the problem alone without proffering solutions is useless. Therefore, there is a need to establish vital considerations for managing the growing problem of e-waste. A critical analysis of existing literature on e-waste seems bereft of a model for effective e-waste management.

The management of e-waste cannot be ignored. It is a problem that must be addressed at the budding stage to ensure that e-waste is well managed. The management of e-waste in Africa is dominated by the informal sector collectors and recyclers as there is very few if any policies such as the take-back schemes as well as modern infrastructure for recycling. This means the need for mechanisms to handle e-waste now before the amount generated proliferates into serious and difficult to manage amounts.

E-waste is a challenge for local authorities especially in terms of its end-of-life management. Consequently, it is currently largely driven by the informal sector in most developing countries. E-waste management in Africa is dominated by a thriving informal sector, collectors and recyclers. In most countries, take-back schemes and modern infrastructure for recycling are non-existent or grossly limited (Balde *et al.,* 2017). It is important to note that the establishment of modern recycling facilities currently, before the problems goes out of hand, will be the best management option for developing countries, as they can curb the e-waste problem while it is still in its infancy and ensure that the future and sustainable development are not misplaced.

### 2.8.1 South Africa

The constitution of the country provides for a clean environment that is not detrimental to the population's health. The National Environmental Management Act, NEMA Act 107 of 1998, the Occupational Health and Safety Act (OHSA) and the Hazardous Substances Act (HSA), Act 15 of 1973, are some of the legislations that attempt to be inclusive of e-waste management. According to Schlep *et al.,* (2009) South Africa and China have been identified for sustainable e-waste recycling technologies by applying United Nations Environmental Programme technology transfer. South Africa is thought to be at the forefront of waste management in Africa and an e-waste management model is to be developed to serve as a blueprint for an approach to e-waste elsewhere on the continent.

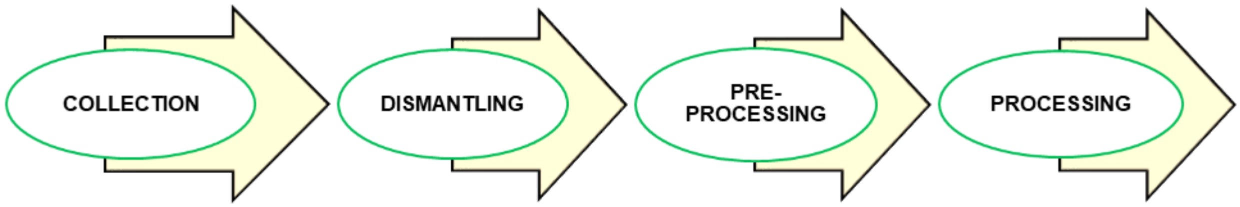
A recent assessment by Pretoria based Basel Convention Regional Centre (BCRC) suggested that except for South Africa, electronic waste was given little or no priority in the SADC countries. This could be because of a lack of awareness of hazardous waste and inadequate legislation, controls and facilities to deal with waste. South Africa has taken great strides towards developing policies, procedures, strategies and legislation for the management of e-waste (Schlep *et al.,* 2009). Finley (2005) cited in Analide (2007) estimated that about 70 % of South Africa's e-waste is thought to be properly controlled.

In South Africa, there are few e-waste recyclers. Some are accredited by the Electronic Waste Association of South Africa (e-waste), such as: Desco Electronic Recyclers, Enviro Serve, Computer Scrap Recycling, and Virgin E-waste Recycling. This means while the standard may not be best there is clear evidence that South Africa has a road map to e-waste management. Although that country's small municipalities still find it challenging to handle ordinary waste, it is even more complex with e-waste. Guerrero *et al.,* (2013) report that it is a challenge for the cities and towns but overall, South Africa is doing something towards e-waste management.

Over 100 formally registered companies operate across the WEEE recycling value chain, thus from collection to processing in South Africa. Gauteng is the central (hub) for the collection, consolidation, pre-processing and processing of WEEE in South Africa (+/- 55%) of the total quantity handled in 2015. Western Cape and Eastern Cape are important provincial aggregation and sourcing nodes.

The South African WEEE industry is governed by the 3R principle that advocates for the reduction, reuse and recycling of such before any other disposal alternatives are considered. The formal WEEE value chain in South Africa consists of four stages. These are: [1] Collection, [2] Dismantling, [3] Pre-processing and [4] Processing, and this is shown in Figure 2.8 below.

Figure 2.8: E-waste Recycling Process




Source: Iydall, Nyanjowa and James, (2017).

This recycling of e-waste is critical as this ensures that the effects of the heavy metals associated with e-waste are minimised. In South Africa, these processes are done by companies with supplies of e-waste from individual recyclers. Although South Africa's e-waste management is not excellent, its management is so far the best in the SADC region. While the flow chart in Figure 2.8 offers an insight into how e-waste is processed, questions remain on how effective it is in managing e-waste. This calls for a critical review of existing frameworks for e-waste management if vital considerations for best practice in e-waste management are to be established.

### 2.8.2 Botswana

The country does not have an e-waste management framework yet, and e-waste represents one of the growing post-consumer waste streams, thus building up a bulged municipal solid waste (UNEP, 2009). Like in any other developing countries, landfilling of electronic waste along with other forms of waste is evitable (Ongondo, *et al.,* 2010). Like other developing countries Botswana lacks accurate statistics on the amounts of e-waste ending up in the landfill.

Mmereki *et al.,* (2012) and Bagale (2012) indicated that in developing countries like Botswana, solid waste management is becoming a daunting task including collection and disposal that is complicated by the invasion of e-waste, particularly computer waste. Generally, the e-waste recycling industry in Botswana is relatively invisible and underdeveloped compared with other neighbouring countries like South Africa. The Botswana Waste Management and Pollution Control (BWMPC) and the city council are responsible for waste management. The waste is taken to Gamudubu a landfill situated about 35 KM from the centre of Gaborone. The council also advises households to craft their safe end-of-life management of e-waste due to lack of WEEE recycling skills (Taye *et al.,* 2014). The authorities charge for waste collection and of note is electronic waste which is also charged along with other forms of waste such as scrap metal, industrial waste and also soil materials. Individuals and companies are allowed to scavenge for reusable and recyclable materials, this is however not done systematically. The participants are also not charged for material recovery.

The Gamudumbu landfill is the main site for disposal in Botswana and it is a regional landfill and run by Kwaneng District Council. It was opened for use in 2009 and serves Gaborone, Molepolole, Mogoditshane, Thmga, Gabane and Tlokeng. The landfill has a capacity of 65 000 tonnes and the land area is 80 hectares, although currently, 30 hectares is underuse. It has a 20-year lifespan. The site has other facilities on site such as two computerized weighbridges, two incinerators for disposal of clinical waste, two landfill compactors, 3 tipper trucks to transport cover material, mostly soil, one bulldozer, one tier cutter for shredding tiers, wood chopper and a standby generator as well as a fuel point. The government has started to initiate the establishment of landfills in different cities.

In Botswana according to Gabaitiri *et al.,* (2012), there is no coordination between the council, landfill managers, west collectors and the communities around Gaborone. This results in mismanagement of e-waste. There is no separate collection of e-waste in Gaborone and thus there is no clear data and literature on the quantity generated and disposed of each year, or consumer behaviour on e-waste disposal and the associated extent of environmental risks. Open dumpsites are a primitive stage of solid waste management in many parts of the world (Sankol, 2013) and this is also common in Botswana.

### 2.8.3 Zambia

According to Zambia Environmental Management Agency (ZAEMA), only a small percentage of e-waste is being recycled and sometimes Zambia sends e-waste to South Africa for recycling. The issue of electronic waste disposal is delicate in Zambia, much like other countries in the Global South (Kanda and Taye, 2011). Zimbabwe and

Zambia do not have government-approved e-waste recyclers; thus, e-waste involves informal recycling in a context of inadequate legislation and continued lack of awareness of the relevant stakeholders. Mukaka and Masiye, (2002) indicated that there is a quasi-linear relationship between population growth and waste produced in Lusaka, Zambia. Thus, the higher the population the more the waste. The e-waste sent to South Africa for recycling means that Zambia is not directly benefiting from their urban mining, because they sell raw waste to South Africa, who in return get the valuable metals. It must however be noted that in terms of environmental pollution the problem is limited. The bulk of e-waste from Zambia is largely the responsibility of South Africa as it is that country that does most of the recycling of e-waste from Zambia.

### 2.8.4 Mozambique

Mozambique's official municipal disposal site is Hulene. It is located 700m from the Airport runway and is surrounded by houses with just a 5m road between the waste and the fences of the surrounding household gardens. Urban solid waste management in Mozambique is the responsibility of municipal authorities. The inadequacy, outdatedness of the equipment and the general lack of systematised information on soil waste in Mozambique constitute a serious problem for a broad understanding of the e-waste situation. Chemicals are part of our daily life; all living and inanimate matter is made up of chemicals and virtually every manufactured product involves the use of chemicals. This means that wherever there is e-waste, humanity is surrounded by a health-threatening environment.

Despite no clear legal instrument on e-waste, Mozambique has some legal instruments dealing with the management of waste in general. These include among others:

[1] Environmental law N. 20/19

[2] National Environmental Policy, Resolution N. 5/1995

[3] Regulation on Bio-Medical Waste Management, Decree N.8/2003

[4] Regulation on Solid Waste Management, Decree N.13/2006

[5] National Strategy for Integrated Management of Urban Solid Waste in Mozambique for the period 2013-2025

[6] Regulation for the Management of Hazardous Waste, Decree 83/2014.

Despite the legislation listed above, there is little being done in treating e-waste as a special waste that requires a governing legal instrument, rather there is a regulation on hazardous waste in which e-waste is not specified but treated as any other form of dangerous waste. It, therefore, follows that e-waste is dumped like any other form of waste without treatment. This leaves it to individual scavengers to recycle e-waste. That as it may, there are no formal entities registered with the responsible authorities to recycle e-waste. Clearly, the aspect of incapacity on the part of authorities is the greatest challenge. (Buque, 2014)

### 2.8.5 Zimbabwe

Gweme *et al.,* (2016) state that despite Zimbabwe being a recipient of ICT, she does not have an e-waste disposal mechanism of her own. The modalities of e-waste problems are little known in Zimbabwe. Wolf and Baddeley, (2012) state that, "the size and the complexity of the e-waste problems are increasing at a much faster rate than the efficiency of our strategies to contain it. Zimbabwe has ratified international treaties such as the Basel Convention in 1989 and the Bamako Convention in 1994. These conventions control hazardous substances but they are not clear as to the specifics such as e-waste. This has seen several African countries, Zimbabwe included, adopting these but failing to domesticate them. This means on e-waste management countries have failed to transpose it into national law.

Vast e-waste is moved around the world for recycling in developing countries using manual processes in backyards resulting in significant contamination of soil, water and air in these countries. This has resulted in the poisoning of many local people engaged in this in areas such as Magaba home industries, in Mbare where electronic junk is burnt daily and areas of informal processing such as Siyaso in Mbare and Gaza land in Highfield (Chitombe, 2013). This then calls for the need to conduct soil and water assays to ascertain the levels of e-waste pollution in the city of Harare.

Zimbabwe has no policy or legislation on e-waste, in general, the EMA prohibits the discharge of hazardous substance into the environment, but there is no specific legislation regulating e-waste. EMA is drafting a document statutory instrument (IS) on e-waste. Meanwhile, however, e-waste is being dumped at Pomona dumpsite and taken away by scavengers. This is against the background that according to Jerie (2014) e-waste represents one of the fastest-growing solid waste streams in Zimbabwe's major cities like Harare. Harare was chosen in this study because it is argued to be the heaviest consumer of ICT products and consequently has more challenges related to e-waste. The general challenge faced by Zimbabwe is the limited capacity and capability of responsible institutions, poor implementation of legal instruments, poor participation among stakeholders and lack of sustainable funding (Maringe *et al.,* 2015). However, it remains to be seen how these factors have impacted upon e-waste approaches being used. Therefore, the focus of this study was to develop a model for effective e-waste management.

According to Jerie, (2014) unlike municipal solid waste the WEEE management system is not well established in Zimbabwe and there is generally a lack of awareness with regards to sound electronic waste management.

Mukoki, (2015) argues that Zimbabwe is grappling with challenges of reducing levels of unsafe disposal and processing of e-waste. This situation is exacerbated by the fact that it does not have an approved law on e-waste nor does it have a specific list of licensed e-waste recyclers. How the existing e-waste management frameworks have managed to fare remains a grey area despite growing evidence that they have not been up to the task. Therefore, this study sought to establish vital considerations for effective e-waste management.

According to Mutau, *et al.,* (2015), there is a fragile interest in e-waste management because there is no e-waste law. This is against the background of an invisible risk to the environment and public health. Zimbabwe has no known official strategy for managing e-waste and like most other countries in the SADC they have not given the problem any attention (Taghipour, 2012)

## 2.9 E-WASTE AND ITS EFFECTS

According to Oteng-Ababio (2012), humanity has been inventive and productive since time immemorial.  This has been beneficial to them; however, these inventions are fast causing environmental problems that are threatening to wipe away humanity if no action is taken to ensure proper e-waste management. The rate of e-products production is seriously high that if not abated the world will not be able to handle the waste that comes with it. Sustainable development is at stake as already the current generations are faced with e-waste problems. It seems the idea of e-waste is currently not prioritised by most developing countries. This is so much so that some do not even have legislation in place to monitor e-waste. This is perhaps because the effects of e-waste are not yet visible to the populations. Consequent to which the effects of e-waste are insidiously developing around.

There are a multiplicity of potential hazards and varied health effects to people after long–term exposure to electronic waste because they contain heavy metals. They are heavy metals because they possess a specific density of more than 5g/cm3 and adversely affect the environment and living organisms if the quantities are more than the optimal levels (Jarup, 2003). They are quite essential to maintain various biochemical and physiological functions in living organisms when in very low concentration; however, they become noxious when they exceed a certain threshold of concentration (Jarup, 2003). Generally, the effects of e-waste are difficult to notice because very few people have bothered to think of what will happen to their electronic goods at the end of their life cycle. It is also because people never bother to imagine a future with all the old electronic goods dumped on different areas without any proper management.

The electronic waste environmental pollution is a topical subject of discussion the world over and this shows that despite the benefits of the electronic revolution, not all that glitters is not gold. Currently, it is difficult to establish the number of people who die due to electronic waste-related illness.  This lack of information on e-waste related death results in the waste being seen as a no threat form of waste. However, e-waste information and statistics from developed countries and other researches shows that indeed e-waste is a formidable predicament that is silently killing people in developing countries with them not noticing.

Table 2.3 below identifies heavy metals that are common in e-waste and discusses them in detail in terms of their potential hazard, source and effect to both the environment and human health. The heavy metals inherent in electronic goods can cause serious health and environmental problems. However, these health problems are little known as the focus in health circles is often on other forms of waste-related diseases such as Cholera, Typhoid and Dysentery. For most these three diseases emanate from poor waste management. Despite this, the heavy metals in e-waste are potentially more lethal. As such, the proper management of e-waste, therefore, requires attention as any failure to properly manage this form of waste may be fatal to both the environment and humanity. The harmful nature of heavy metals in e-waste is discussed in Table 2.3 below where its effects on the environment and human health are explained. As the explanations show, there are serious problems associated with e-waste, some of which are irreversible.

**Table 2-3: E-Waste Sources and Their Impact**

| HEAVY METAL | POTENTIAL HAZARD | SOURCE / E-WASTE COMPONENT | ENVIRONMENTAL / HEALTH EFFECTS |
|---|---|---|---|
| Lead | Lead dust | Cathode ray tube (CRT) glass, Batteries, Solder, Older printed circuit boards | Highly toxic metals have caused extensive environmental contamination and health problems in many parts of the world (Jaishankak, *et al.,* 2014). In humans, they can cause damage to the nervous system, anaemia, increased blood pressure, birth defects and brain disorder. Chronic toxic effects on plants, animals and microorganisms in the environment.<br><br>Lead is the fifth most widely used metal after Iron, Aluminum, Copper and Zinc (Agarwal and Wankhede, 2006), used in batteries, cable sheeting |
| Cadmium | Cadmium dust | Alkaline batteries electrode, phosphor coating on CRT glass, used as a plastic stabilizer and is also found in chip resisters<br><br>Predominantly found in fruits and vegetables due to the soil to plant transfer. | Humans get exposed to it by inhalation and ingestion and suffer from acute and chronic intoxication (Jaishankak, *et al.,* 2014). It affects mainly the kidney (Mahurpawar, 2015). Can also cause bone problems, and lung cancer (Balch, 2006). |
| Mercury | Mercury vapour | Telecommunication devices, mobile phones, batteries, thermostats, fluorescent tube. | It spreads out in bodies of water where it is transformed to methylated mercury and can easily accumulate in living organisms mostly fish. It causes nerve and brain damage and birth defects |
| Barium | | Is commonly found in spark plugs and fluorescent lamps. | It can cause brain swelling, muscle weakness and damages the heart and liver. |

| | | | |
|---|---|---|---|
| Beryllium | Beryllium dust | An alloy in televisions, calculators, computers and other electronic devices. | It can settle as dust in the air and may result in berylliosis or other forms of skin and lung diseases. This can also cause cancer.<br><br>Beryllium is a human carcinogen, causes lung cancer, inhalation of its dust, fumes or this causes diseases such as berylliosis in lungs (Michele, 2002) |
| Arsenic | | Found in light-emitting diodes (LEDs). | It is a known human carcinogen.<br><br>Arsenic is a poisonous metallic element. It can be dust or soluble (Townsen, 2011), exposure to causes various diseases like cancer, cardiovascular diseases, can disrupt cell communication |
| Hexavalent Chromium | | Is found in metal parts of electronic equipment | An anti-corrosive coating on screws, rivets, plugs, switches. If absorbed in the human body, it can cause damage to DNA. |
| Brominated Flame Retardants | | Used in electronic products as a means for reducing flammability | Its presence in plastics makes recycling dangerous and difficult. |

Source: Adapted from Nageswara, Rao (2014).

The various heavy metals that are found in electronic waste comes in different amounts depending on the type of appliance. This means it is possible to establish the number of heavy metals that have been deposited into the environment based on the knowledge of gadgets that would have fallen obsolete within a given year. This is critical in e-waste management as well as in the extraction of important metals from e-waste. The components are shown in Table 2.4 below. This means that for every given e-waste that has been sent to the dumpsite or for recycling, it is possible to tell what it would have added to the environment in terms of heavy metals.

Table 2-4: Material composition of four main e-waste categories

| ***MATERIAL*** | **LARGEHOUSEHOLDAPPLIANCE** | **SMALL HOUSEHOLD APPLIANCES** | **ICT AND CONSUMER ELECTRONICS** |
|---|---|---|---|
| ***Ferrous metals*** | 43 | 29 | 36 |
| ***Aluminium*** | 14 | 93 | 5 |
| ***Copper*** | 12 | 17 | 42.3 |
| ***Lead*** | 1.6 | 0.57 | 0.29 |
| ***Cadmium*** | 0.0014 | 0.0068 | 0.018 |
| ***Mercury*** | 0.000038 | 0.000018 | 0.00007 |
| ***Gold*** | 0.00000067 | 0.00000061 | 0.00024 |
| ***Silver*** | 0.0000077 | 0.000007 | 0.0012 |
| ***Palladium*** | 0.0000003 | 0.00000024 | 0.00006 |
| ***Indium*** | 0 | 0 | 0.0005 |
| ***Brominated plastics*** | 0.29 | 0.75 | 18 |

| | | | |
|---|---|---|---|
| ***Plastics*** | 19 | 37 | 12 |
| ***Lead glass*** | 0 | 0 | 19 |
| ***Glass*** | 0.017 | 0.16 | 0.3 |
| ***Other*** | 10 | 6.9 | 5.7 |
| *Total* | 100 | 100 | 100 |

Source: Rao, (2014).

Used Electronic and Electric Equipment (UEEE) cause health hazards such as asthmatic, bronchitis, DNA damage, endocrine and hormone disorder, lung and liver cancer, fertility problems, genetic mutations and according to Zeng *et al.,* (2017), as well as kidney, liver and lung damage. This means that it is important to have a picture and understanding of the levels and quantity of heavy metals in each IEEE. The knowledge of what amount of which heavy metal is carried by what form of e-waste helps and enable proper management of such product. This is so because it will be possible to follow up on products with extreme levels of heavy metals for proper management.

Although Table 2.3 and Table 2.4 have highlighted the problems associated with e-waste a lot of other vital considerations for effective e-waste management for cities in developing countries can be discussed. This is the common thread running through almost all the current studies. There is a need to establish the vital considerations for best practice in e-waste management. To understand the full weight behind such a need, there is a need to have a general appreciation of the environmental and health hazards associated with e-waste mismanagement.

### 2.9.1 ILLEGAL DUMPING OF E-WASTE AND ENVIRONMENTAL PROBLEM

According to Manyanhaire, *et al.,* (2009), illegal dumping is the improper and or unlawful disposal of waste on land, water or at any location other than a permitted landfill or facility. It is also referred to as "open and midnight dumping". According to Jerie (2011) when allowed to continue causes dangerous chemicals to leach out of these dumps into drinking water supplies and pollute surface water. Burning of e-waste at undesignated places can lead to the release of toxic smoke and harmful substances into the atmosphere ($SO_2$, $CO_2$, CO) only to come down as acid rain in surrounding areas and even areas far off the original place (Chifamba, 2007). This is very destructive to crops and livestock as well as human health.

Tsiko and Togarepi (2012) indicated that the majority of high-density suburbs in Harare such as Mbare, Budiriro, Mabvuku, Glen View and Kuwadzana are characterized by illegal dumping due to erratic waste collection systems and disposal service. These are the residential areas that sometimes go without piped water for some time resulting in residents at times digging shallow wells to get underground water. This exposes them to heavy metals as uncollected and illegally dumped e-waste decompose and pollute the underground water system.

Table 2.4 above documents various types of heavy metals, their hazardous components such as antimony trioxide, selenium, chromium, manganese and others. These cause health hazards to human beings and negatively affect the environment (Namias, 2013). These cause most of the adverse health effects in humans (Shah and Shaikh, 2008). This is a serious reflection on the potential of e-waste to cause both environmental and human health problems in future. As this is the case, there is a need to ensure that the current and future generations enjoy the electronic revolution and put in place proper e-waste management strategies.

Merely anecdotal evidence is available on the production, management and recycling of e-waste in most developing countries and only 41 countries in the world collect international statistics on e-waste (Balde, *et al.,* 2017). This means that most if not all developing countries are not collecting e-waste data because they do not see the need to have this, as this is regarded as a non-issue which is likely to just consume from their national budgets, thus depriving other sectors of the economy that are regarded as critical. This is against the fact that the proliferation of increasingly rapid technological advances in electronics means that the volume of e-waste generally is large and growing. Which in turn contributes to health problems that eventually affecting the other so-called critical sectors.

According to Oteng-Ababio, (2012) the electronic detritus that has come to be known as e-waste which is a product of 'hyper technology' that is hailed as a crucial vector for future modern societal development has a not so modern downside to it, thus electronic waste. The fact is that the increasing "market penetration" in the developing countries 'replacement market' in the developed countries and high 'obsolescence rate' make e-waste one of the fastest-growing waste streams and the resultant waste is posing a serious challenge in disposal and recycling and creating ugly solid waste management scenes in most developing countries.

The fact is that managing the normal waste from households in the developing countries already appears to be an insurmountable task and it is therefore seen as a more complicated task if the e-waste from developed countries finds an easy entry into the developing countries all in the name of trade. Rayputje, (2013) regards it as a novel addition to the ever-growing hazardous waste stream. Solid waste management which is already a massive task in developing countries, is being more complicated by the invasion of e-waste. Unorganized dumping of solid waste is predominant in developing countries like India and cause adverse impacts to the environment. Open dumps unfortunately are still the means of disposal of solid waste in developing countries where solid waste is dumped in an uncontrolled manner. This can be detrimental to the urban environment.

Panda, (2013) states that dumping of electronic waste is one of the by-products of this urbanization process which has become a major problem in our society. Environmental scientist found that soil in the e-waste dumping areas is often contaminated by heavy metals and organic compounds (Zhang *et al.,* 2012). E-waste discharge in water causes harm to aquatic life such as plants, animals and micro-organisms. The toxic substances in e-waste are the reason for severe physiological defects, infertility, breathing disorders, skin problems and cancer among e-waste processing workers, yet according to Patil, (2016) e-waste are just but a category of waste that barely existed 20 years ago yet now represents the biggest and fastest-growing waste. Hence the need to dig deeper into e-waste management issues and to the roots of it as evidence all points to a serious problem.

Information and communication technology have revolutionised our economies, industries and our lives. However, e-waste is generally fast becoming a negative spin-off to the development as in most cases toxins from e-waste fall out from open-air burning affects the local environment and broader global air currents by depositing highly toxic bi-products in many places throughout the world. The heavy metals contamination in the environment is of major concern because of the toxicity and threat to human life and the environment as evidence from Skamania and Gandhimathi, (2012) shows that the concentration of heavy metals was studied in the soil sample collected around the municipal solid waste open dumpsite and showed serious concentrations.

As human population and human activity increased, the effects on the biosphere could no longer be ignored. The developing nations are beset by innumerable problems of e-waste. This has caused a rather impending disaster which will be precipitated by the single-minded efforts of industry to make a profit (Walter, 1981). To the developing countries it seems the problem is not vivid although the cataclysmic consequences of pollution are remote, they should not be ignored. Given the political and economic jockeying between the first world nations and the developing nations around e-waste, it is very clear that the future of the developing countries is bleak because while they desire development in all forms to include the electronic revolution, it should not be ignored that the management of waste, particularly e-waste, is difficult because of poor technology. So far, the evidence does not indicate that human health has been deleteriously affected by e-waste and therefore uneconomic and too expensive to restrict production simply because there is a potential danger. However, despite such an understanding of the scale of e-waste mismanagement costs, there remains a need to search for vital considerations to manage e-waste effectively. Electronic products contain lead primarily in two forms that are metallic lead in electrical solder on printed circuit boards and lead oxide used in CRTS. Exposure to them damages blood, reproductive, endocrine system and kidney damage. Mercury in bulbs, flat-screen displays and older types of laptop batteries, cell phone, and lead to brain and kidney damage as well as damage of the central nervous system. When the mercury in electronic devices meets water, either through leaching from landfills or simply throwing electronic devices into water bodies, it becomes methylated or highly toxic methylene mercury. Methylene mercury builds up in fish, shellfish and animals that eat fish and it becomes more concentrated as it travels up the food chain where ultimately human consume it.

## 2.10 ELECTRONIC WASTE AND WOMEN AND CHILDREN

Children and women are at risk more from heavy metals, flame retardants and PAHs when they are exposed to e-waste or when these substances are released by open e-waste burning. During the extraction of targeted metals workers do not use PPE and are exposed to fumes and solvents thus endangering their health (Mandevere 2016). This is very common in most developing countries as women and children especially, are mostly involved in the informal recycling of e-waste and thus, they endure the dumpsite smoke and all the associated waste to survive. The toxic metal elements can include impairment and dysfunction, which include the blood and cardiovascular, eliminative pathways (colon, liver, kidney, skin) endocrine (hormonal) energy production pathways, as well as enzymatic, gastrointestinal, nervous (central peripheral) reproduction and urinary (Bharti, 2012) pathways.

Many industries discharge waste directly into streams, lakes, oceans as well as in the open land and that contaminates the groundwater (Bharti, 2003). This in the end affects women and children most since they are the ones who use such resources daily. This is worsened by the fact that currently there are few studies and limited data on the impacts on the environment, women and children and the informal disposal and processing of e-waste. Heavy metals entering the ecosystem may lead to geo-accumulation, bio-accumulation and bio-magnifications and thus end up in food chain contamination by heavy metals affecting the vulnerable. This has become a topical issue in recent years because their potential accumulation in bio-systems through contaminated water, soil and air are critical and capable of causing serious health problems.

In today's "throw-away society", the desire for devices with better and newer state of the art technology is leading to a continuous expansion of the electronic market and shortened innovation cycles of electrical and electronic equipment (EEE). This is adding to the already ubiquitous heavy metals in the environment and some of which are biologically essential, but becomes toxic with increasing dosage as is happening now if the multiplication of e-waste and associated heavy metals. Bharti, (2012) states that heavy metals may enter the human body through food, water, air or absorption through the skin when they come in contact with humans in agriculture, manufacturing, pharmaceutical, industrial or residential settings. This means human being, especially women and children, are at risk. Thus, this calls for the need to establish key elements for best practice in e-waste management. The section below presents some of the conventions on dangerous substances.

## 2.11 INTERNATIONAL CONVENTIONS

The world having been faced with a serious environmental problem that ended up affecting human health, has devised a multiplicity of agreements and conventions to handle and reduce the effects of hazardous substances on both human being, animals and the environment. Some of these conventions, treaties, agendas and agreements are discussed below.

### 2.11.1 The Basel Convention

This deals with the control of the transboundary movement of hazardous waste and its disposal. These substances include e-waste. It aims at protecting both the environment and human beings from the effects of hazardous waste generated by humanity across the world.  The hazardous aspect in the case of e-waste is heavy metals such as lead, mercury, arsenic and others. The convention is not directly talking of e-waste but refers to some dangerous substances that are inherent in e-waste. The convention also deals with the disposal and movement of dangerous substances. It has been amended along the way to attend to new issues to do with hazardous waste and electronic and electrical waste which cannot be ignored in this case. At the 4$^{th}$ meeting of the conference of parties, the convention was amended to include e-waste issues. Further to this Nairobi declaration of 2006 allowed for sound, proper and modern environmental management of e-waste (United Nations Environment Management Group, 2017).

### 2.11.2 Minamata Convention

This was established in 2013 as a global treaty to protect human health and the environment from the effects of mercury. Mercury is a heavy metal that is commonly used in electronic and electrical goods production. The ubiquitous use of mercury means a lot of e-waste that is thrown away goes along with mercury and pollutes the environment. This convention, therefore, seeks to control the release of mercury into the soil, water and atmosphere which affect human health in the end. This convention does not directly talk of e-waste but deals with one of the major heavy metal that is used in the production of electronic goods. The production of mercury-free electronic good would therefore go a long way in reducing the effects of mercury on human health.

### 2.11.3 Bamako Convention

This is a treaty of African countries prohibiting the importation of any hazardous waste. This is closely linked to the Basel Convention, but the emphasis is on prohibiting the importation of all hazardous waste. E-waste is one of the hazardous wastes on the increase and its importation into African countries must be reduced as they do not have the financial power and technical ability to treat, recycle or even properly dispose of it. The prohibition of the importation of e-waste to such incapacitated countries will help as e-waste is very hazardous to both the environment and human health. The fact that the e-waste is dumped on African countries points to the critical need for the Bamako Convention to reduce such importation, especially of second-hand electronic products.

### 2.11.4 Durban Declaration

It is an African declaration whose mandate is to control the movement of e-waste to Africa alongside other international bodies, it calls on and demands that countries review their existing legislation, improve their compliance with legislation and amend existing legislation regarding e-waste management. This is an important declaration as it seeks to protect the developing African countries from the ever-increasing e-waste. The ability to manage e-waste is very limited in developing countries of Africa and as such prevention is better than cure.

## 2.12 E-WASTE IN DEVELOPED COUNTRIES

In developed countries, manufacturers of electronic goods take back their products at the expiration of their life span, for safe destruction and, or, recovery of important materials (Kuper and Hojsik, 2008, Oteng-Ababio, 2012). According to Sitaramaiah, *et al.,* (2014), Nokia and Samsung have takeback schemes in the European Union, Australia and parts of Latin America. This is, however, unavailable for Africa (Sitaramaiah, *et al.,* 2014) where chronic keepers sometimes referred to as "pack rats" tend to hoard long obsolete items and yet these can be recycled and urban mining can give birth to productive tendencies and valuable items will be returned from such products which are kept by government and individuals for perceived benefits in this regard. The expense of proper electronic waste disposal by companies in the developed world leads to the exportation of e-waste to developing countries by the developed countries. This electronic waste transfer is fortified by the lack of legislation in developing countries to compel these companies to monitor their products from the cradle to the grave and take back their products and bear the associated costs of treating and disposing of these (Meltzer, 2014; Sitaramaiah, *et al.,* 2014). The developed countries seem to notice the poverty of developing countries and their different positions regarding e-waste. The developed countries are capitalizing on that, to keep burdening African countries with e-waste in the name of electronic revolution and associated donations even though according to Oteng-Ababio, (2012) some of the donated and imported electronic products will be already grey thus increasing e-waste to developing counties.

According to Behdad, (2010), America currently owns nearly 3 billion electronic products. These products join electronic waste as they become obsolete products. In some cases, these obsolete products find their way to developing countries (Behdad *et al.,* 2009 and 2010). States such as California are crafting legislation that will require manufacturers to pay for the cost of the end-of-life treatment of electronic products (Electric Take Back Coalition, 2008). The United States talks of the Responsible Electronic Recycling Act (RERA) which is mandated to ensure that untested or non-working electronics (e-waste) is not exported to developing countries, requiring that it be processed initially in the US and thus creating 40 000 jobs in the recycling of electronic waste (Behdad *et al.,* 2009 and 2010). It should however be noted that due to some strong legal instruments some companies in the developed world are sacrificing third world countries.

Each year between 20 and 50 million tonnes of electronic waste are generated worldwide. This could bring serious risks to human health and the environment (Behead *et al.,* 2009 and 2010). Be this as it may, more than half of this waste is a responsibility of the developed countries at local levels or as transnational companies across the globe. Countries like Switzerland have very advanced methods of e-waste management (Behead *et al.,* 2009 and 2010). Their landfills are advanced and are categorized by the nature, toxicity and complexity to treat the waste (Behead *et al.,* 2010 and 2009). Any areas where e-waste has been deposited or have infiltrated the ground are labelled "polluted sites" and Switzerland has a well-developed network of waste management facilities (Shah and Shaikh, 2008).

Switzerland is active in the transfer of technologies and implementation of environmentally friendly disposal of e-waste in Asia, Latin America and Africa (Namias, 2013). A pilot project in South Africa together with the world market leader Hewlett-Packard for the treatment of electronic waste (e-waste) is a success story (Behead, *et al.,* 2010). It must however be noted that this privilege is not available in most developing cities to including Harare. This, therefore, means that a lot must be done by developing cities for them to reduce the effects of e-waste on both the environment and human health. This might mean that the developing world needs to advocate for the companies and parastatals from the developing world to be responsible for the e-waste they generate and export to developing countries by ensuring that they follow up and take back their products when they become obsolete. This can be done through a partnership with local companies who will then collect, process and recycle e-waste on their behalf. However, it remains to be known how cities in developing countries can effectively manage their e-waste. To fathom the magnitude of difference in waste management between the developed and developing world, the section below focuses on e-waste management stages in developed countries.

### 2.12.1 E-WASTE MANAGEMENT STAGES IN DEVELOPED COUNTRIES

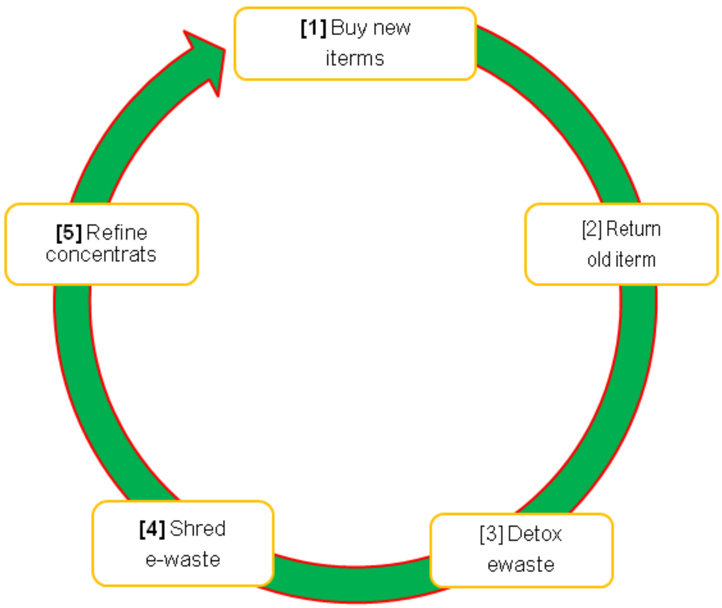
The wheel of e-waste is a strategy that has been employed in most developed countries as a strategy to manage electronic waste. This management tool has however been limited specifically to developed countries. The cycle is critical to e-waste management as it is named the “wheel of life” suggesting that it goes a long way in handling and managing e-waste and its associated problems such as human health threats.

### 2.12.2 E-WASTE “WHEEL OF LIFE”

There are five stages as shown in Figure 2.9 below on the management of e-waste in the developed world and these stages constituted that they have termed the e-waste wheel of life. Stage one is the level at which individuals and companies buy various electronic goods such as bulbs, mobile phones, radio, televisions, and several others. These then progress to their grave whose gestation period is varied with manufacturers as well as the type of product. The life span ranges from seconds as some bulbs do not last two years especially with certain products that are manufactured in a manner that the consumer should return to the supplier faster.

Stage two involves the sending back of an electronic gadget that is no longer useful, that which has come to the end-of-life. This product is no longer useful to the owner and so it is returned to the manufacture for dismantling, recycling and proper disposal of the unwanted waste. This stage, however, is not identical across countries as it is determined by individual laws of a given nation. The return back concept is more dominant in developed countries than the developing countries because they have legislations that provide for returning the obsolete electronic goods. In developing countries, it is rare as most of these do not have any law compelling the producers of electrical and electronic goods to take back their products when they become obsolete.

Figure 2.9: Wheel of Life of E-waste Management




Sources: Shah and Shaikh, (2008).

This situation is even more complex in that developing countries cannot return obsolete goods because most of them, are goods that were manufactured outside of their borders and no laws are compelling such producers to take them back. Neither are there any parastatals set in developing countries to take back such. Stage three is the detoxification stage in which the returned materials are processed and thus removing important components of the e-waste and this helps to reduce dilution and contamination as the dangerous substances will also be removed. Stage four involves the shredding and collection of similar materials for refinement and the final stage which is stage five is the refinement stage and here the important materials are then reused while the useless material is sent to the landfill as the place where it will be properly disposed of. This is unlike in most developed countries where dumpsites are the endpoint of such toxic and untreated waste.

As it is, this cycle of e-waste management is employed more as ammunition to shoot down the environmental and health problem in developed countries such as Switzerland where this has been employed successfully. This is unlike in developing countries such as Zimbabwe where the likes of Makwara (2013) laments the lack of separation of household solid waste resulting in the birth of an assortment of domestic solid waste to include e-waste which is then ultimately dumped on the dumpsites that are not properly constructed resulting in underground water contamination. Thus, the lifecycle of e-waste management presented in Figure 2.9 fails to holistically prescribe solutions to the problems of e-waste in developing countries.

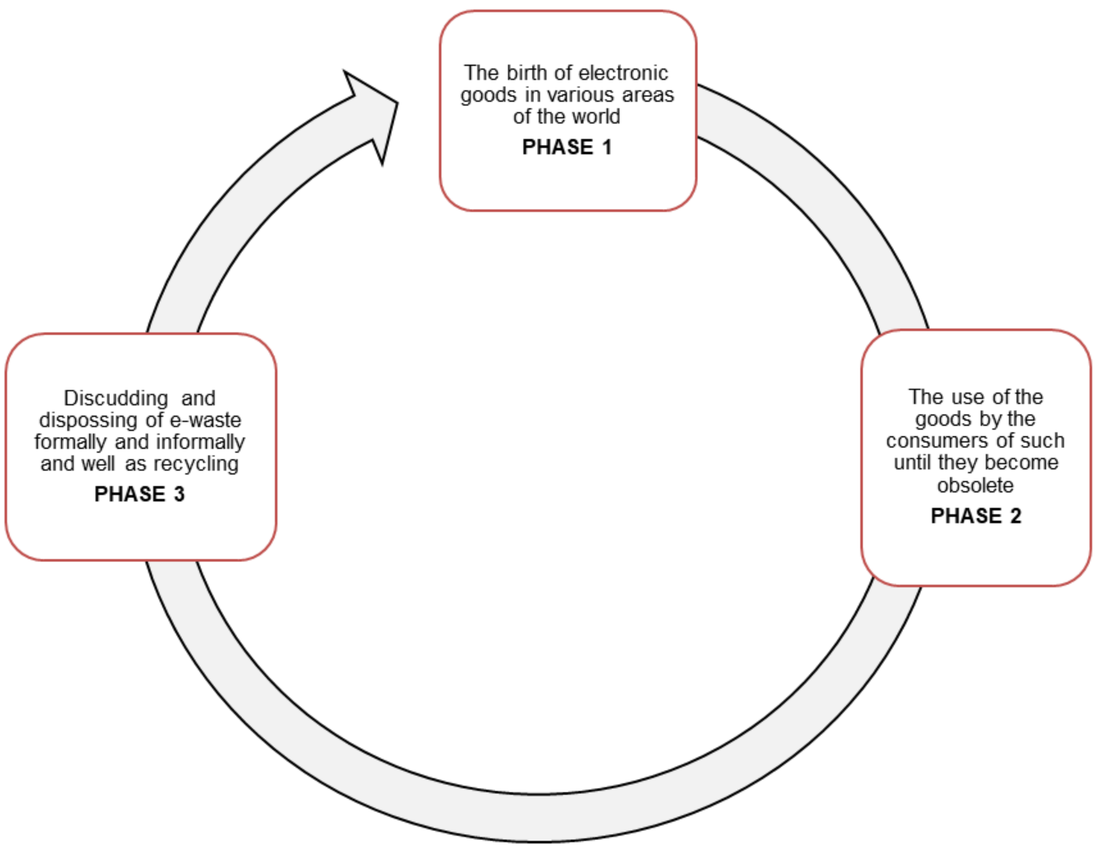
The implication and meaning of the e-waste cycle in Figure 2.9 above show that the manufacturer of electronic gadgets has an obligation of ensuring that at the end of life of their products they should take back the electronic item for safe disposal, if not recycling. This is a critical component of e-waste management. As human beings, electronic goods are important when one buys a new gadget just the way we welcome a new born into the family. When death comes in every culture and society the dead are given their last respect by way of a decent burial and possible future memorials, this is just like e-waste, its proper take-back and ultimate recycling gives it value again and again. Thus, sending one’s absolute electronic product is equivalent to paying last respects to one's obsolete electrical good. In cases of death, we give our loved ones a decent burial because they were dear to us, they helped us in several ways and therefore they deserve a good burial. The same can be said to our electronic good because they once were critical to us and helped us in many ways. So, when they become obsolete, we should ensure that they are safe and well-disposed.

Contrary to most cities in developing countries, there are no such e-waste management practices in place. This is because for developing countries the technology is still primitive that they cannot do proper e-waste management. This is further worsened by the fact that the manufacturers of most goods for example in Harare, Zimbabwe are international and cannot follow up on their products. This leaves Harare with no option but to continue with little or no knowledge of its environmental future, especially with e-waste in the picture.

### 2.12.3 LIFE CYCLE OF ELECTRONIC EQUIPMENT

The electronic products follow certain stages, the day of production, use and the final day of disposal. The life cycle of e-waste is in phases as shown in Figure 2.10 below. The phases in Figure 2.10 below are important in the management of e-waste. This is because an understanding of each phase ensures that critical aspects are managed, for instance at production it is important to reduce the levels of heavy metals and other toxic substances in electrical and electronic goods. In phase two it is important to educate the customers on possible management options when their products become obsolete, as well as the final phase in which the municipality, residents and other players need to work together to manage the end product whose negative effects on the environment and human health are serious if not managed.

Figure 2.10: Life Cycle of Electronic Equipment




Source: Shah and Shaikh, (2008).

The first phase which is Phase 1 involves the manufacturing and production of electrical and electronic products and once produced the product enters the value chain. This is done in various industrial areas across the globe where they also practice environmental management as this is where the heavy metals are assembled thus the entry point into the world of e-waste. This, therefore, becomes the first step into the generation of e-waste.

Phase 2 involves an analysis of products to establish whether certain given electronic products can be refurbished or are to be discarded as e-waste. This is the screening process to which products can be recycled, reused or to be destroyed completely and be processed into some other electrical and electronic goods.

Phase 3 is the end stage to which the product produced in stage one and assessed in Stage 2 overtime becomes tired and is termed e-waste. This phase involves the first stage of Phase 3 which is pre-processing of e-waste, thus basically collecting such obsolete e-equipment. Stage 2 of Phase 3 then involves the treatment of the collected e-waste and finally Stage 3 of Phase 3 is sorting and dismantling of e-waste to take the necessary metals and properly dispose of the useless material.

The cycle is important because as Gupta and Ganesan, (2014) indicated, the lack of raw materials needed for the manufacturing of electronic and electric equipment are in short supply, therefore managing e-waste well will reduce dependence on imports of expensive minerals that are used in the production of e-waste. This means that effective e-waste management can provide secondary resources that reduce needy for virgin raw materials and thus reducing the expense in the manufacturing of electrical and electronic products. The electronic life cycle presented above fails to proffer vital considerations for effective e-waste management for cities in developing countries. The issue of developing a model for effective e-waste management for cities in developing countries seem to have escaped the academic radar as very few models have been put forward to help explain e-waste management.

## 2.13 E-WASTE IN DEVELOPING COUNTRIES

E-waste is an emerging fast-growing waste stream with complex characteristics (Balde, *et al.,* 2015). It is causing severe health concerns for millions of people around the world, mostly in developing countries of Africa, Europe and Asia (Sitaramaiah, 2014). E-waste is responsible for 23% of death in developing nations which are linked to pollution and other environmental impacts (Sitaramaiah, 2014). This e-waste is expected to grow in developing countries because there are crude and inefficient techniques used to extract material components during recycling and that the developed countries are exporting products and industries that produce electric equipment to developing countries because it is cheaper (Blade, *et al.,* 2014) and developing countries like Zimbabwe has fewer regulations regarding electronic equipment manufacturing and the subsequent disposal (Kidd, 2009). In essence, Zimbabwe does not have an e-waste law and regards it as any other waste governed by the EMA of 2002. The developed countries leave it up to developing nations to clean up the mess (Balde, *et al.,* 2015). In 2014 the amount of waste generated in Africa was 1.9 million tonnes (Balde, *et al.,* 2015). This is against the background that only Cameroon and Nigeria have enforced national e-waste related legislation in Africa and South Africa is working on a model for e-waste management (Blade, *et al.,* 2014). This means that very few governments' reports on electronic waste are available in Africa (Ongondo, *et al.,* 2011).

Developing countries need an integrated electronic waste control policy since there are no measures in place to educate customers on how to deal with obsolete electronic equipment such as mobile phone handsets, as people are unaware of the hazards these pose (Meltzer, 2014, Sitaramaiah, *et al.,* 2014). The developing countries are said to produce e-waste faster than developed countries and it is estimated that the volume of obsolete computers generated in the developing countries will exceed that of developed nations by 2018 (Sitaramaiah, *et al.,* 2014). It must however be noted that the irony and gist of the matter is that, developing countries are merely consumers and not manufacturers of the electronic equipment that will then give birth to e-waste (Kuper and Martin, 2008, Sitaramaiah, *et al.,* 2014, Meltzer, 2014)

The pathetic fact about e-waste in developing countries of Southern Africa and the rest of the world is that according to Sitaramaiah, *et al.,* (2014) the United States (US) discards about 30 million computers and Europe 100 million mobile phones annually and most of them find their way to Africa in form of e-waste to contaminate their environment and harm their health. In contrast, developing countries without viable landfills or recycling apparatus simply dump e-waste out in the open (Bogala, 2012). This could be another form of colonization in which technology and the electronic revolution are used as ammunition to shoot down the environment of developing countries like Zimbabwe. This process is made possible by the fact that there are legislative gaps in the management of e-waste and worse so, these gaps are difficult to close as the vicious cycle of poverty keep telling the developing countries to keep on stretching their hands and bowels to the developed countries for technological panaceas.

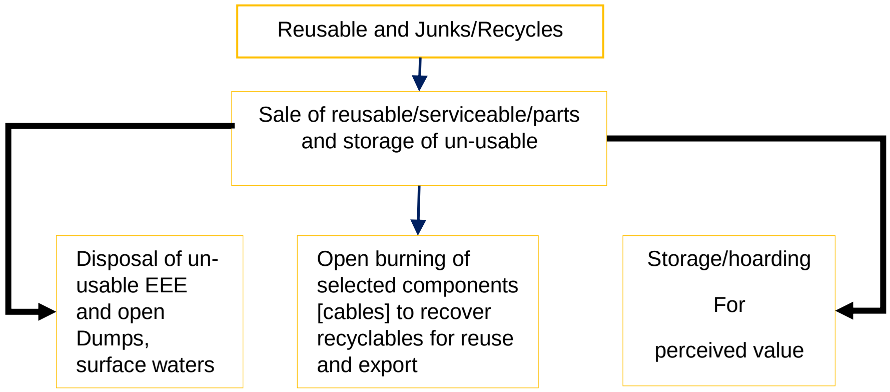
A sad living example of the African case is the Agbogbloshie of Ghana which has been nicknamed the digital graveyard (Sitaramaiah, *et al.,* 2014) because it has become a desolate place with no vegetation and fish in the water due to e-waste which has turned the water into concentrated sludge and which is life-threatening (Sitaramaiah, *et al.,* 2014). This place is now considered the most toxic place on Earth surpassing Chernobyl of Ukraine (Sitaramaiah, *et al.,* 2014). This is alarming, as most developing countries cannot deal with e-waste. Countries like Botswana, Zimbabwe, Mozambique, Zambia and others like them, are only consuming without a database of the amount of e-waste being generated (UNDP, 2008). This is further exacerbated by the fact that there is little or no technical capacity to dismantle and retrieve usable components and lack of market for such in case of recycling and the destination for such e-waste in countries like Mozambique are mostly uncontrolled dumpsites with no or very little treatment and separation of waste (Medina, 2010).

Mandevere, (2016) posits that the fact that dumpsites are often located closer to residential areas with no soil tests or environmental impact assessment reports, one cannot ignore the potential danger of lixiviation with soil, water and air contaminates since no treatment is given to electronic waste (Balde, *et al.,* 2015). Thus, this calls for the need to conduct soil and water assays to determine the level of e-waste pollution. Quantifying the levels of e-waste pollution would other than being used to gauge the effectiveness of available frameworks for managing e-waste be used to develop a model for effective e-waste management.

### 2.14 E-WASTE RECYCLING IN DEVELOPING COUNTRIES

The most primitive e-waste management is common in Africa and other developing countries. Zimbabwe is a party to this problem and Figure 2.11 below shows how e-waste is being handled in developing countries of Africa. One of the largest e-waste dumpsites in the world is the Agbogbloshie site in Ghana (Tue *et al.,* 2016). Most African countries import electronic goods from the developed world and in some cases, transnational companies establish electrical and electronic goods-producing industries in countries in the developing world. Most of the locally produced electronic goods being produced by small local producers do not produce large amounts of e-waste. When they import electronic goods some as new products and some as second-hand goods, they then sell these, especially those that will be functional and from some, they take spare parts. They then dispose of those that are of no use to the dumpsite. Some do open burning of such waste to recover critical components such as cables and other recyclables. It is also important to note that in most cases the recycling process involves very primitive methods, as the recyclers do not have any skills and technologically modern equipment to use for recycling, Figure 2.11 below shows how e-waste is managed in Africa.

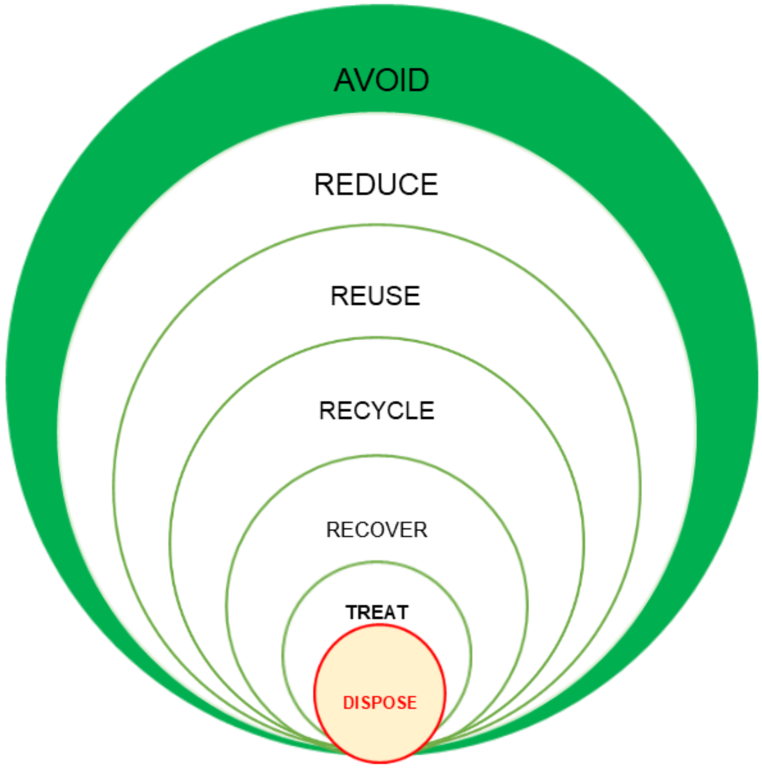
Figure 2.11: Electronic Waste Management Practices in Africa




Source: Adapted from Lydall, Nyanjowa and James, (2017).

In most cases, some electronic goods are stored in offices and households in anticipation of possible use in future. This is very common with government offices in Harare, Zimbabwe where bureaucratic procedures have to be followed to dispose of old computers and other old electronic goods. Also, of note are household which keeps holding on to useless electronic goods for perceived possible future use like the Wiztech decoder which is no longer in use, but always displayed in most households in Zimbabwe. It must however be noted that while hoarding of such useless electronic goods is perceived as keeping e-waste, it must be noted that such e-waste is better than that discarded as the thrown away e-waste is decomposed and pollute the environment and or is recycled in the most primitive method, polluting the environment again and also harming the health of the recyclers. The disposed of e-waste, therefore, becomes the active type of e-waste while those kept and undisposed becomes latent and dormant.

Figure 2.12: Waste Management Hierarchy




Source: Adapted from Edith Cowan University, (2008).

These principles however require that there be resources to fully implement them to the benefit of environmental management. This, therefore, means that there is a need to look closely at issues surrounding these principles and resources in developing cities like Harare of Zimbabwe. The management of e-waste is critical, just like any other form of solid waste management. It must however be noted that according to the ILO, 2007 waste classification, e-waste is a form of hazardous waste and is overwhelming in the cities of developing countries like Harare in Zimbabwe. Though the diagram above has presented a hierarchy for waste management, there is a need to focus on the development of vital considerations for best practice in e-waste management.

In trying to properly manage this form of waste, the most desirable method is to avoid the use of electronic goods with a short life cycle. This is however impossible because people cannot just avoid technology and thus resorting to cheap electrical goods that do not last and quickly turn into waste. It is also critical to reduce electrical and electronic goods which will reduce e-waste in the long run. This reduction is however close to impossible because with population growth comes a growth in the desire to be computer literate, to be internationally connected and to live a modern life. This means that reducing the use of electronic good is difficult if not impossible unless a new technology is developed to replace the current one.

The other options are to reuse, which is very common in developing countries as they sell and buy second-hand electronic goods for use again. In fact, according to Gupta and Ganesan, (2014), most of the electronic goods from developed countries to developing countries are not new. The other available option is recycling which is however difficult in developed countries as they lack the technology to recycle. In cases where recycling is done the methods are very rudimental, skeletal and primitive. This is why Rajagopalan, (2005) said that recycling is not a solution to managing every kind of waste material; in fact, recycling technologies are unavailable especially in developing countries like Zimbabwe. This makes the management of e-waste somewhat difficult as there is few if any available options for its management in developing countries. Recovering important material and treating the unwanted hazardous material in e-waste is also difficult because of the same reasons that developing countries and their municipalities such as Harare in Zimbabwe are crippled and cannot do anything with regards to e-waste management as they are faced with more e-waste exported to them in the name of technological advancement.

**2.15 URBAN MINING**

According to Okwu and Onyeje, (2014), this entails valuable resources in cities and towns that can be recycled and re-used and in particular, recycled e-waste. This is turning trash into treasures, like recovering valuables from e-waste. It is like turning waste into energy. Urban mining of e-waste can also be called e-mining. This e-mining does not only provide valuables such as gold and silver but also creates employment. The electronic revolution in Zimbabwe has seen the coming up of e-waste problems as the voice of business keeps calling electrical goods producers to keep producing low standards goods which quickly turn to e-waste, this makes Africa seem a dark continent when it comes to waste management. This has also come with benefits that, there is a need for a SWOT analysis of e-waste in Zimbabwe to establish the strengths, weaknesses, opportunities and threats surrounding electronic waste. Tabulated below in Table 2.5 is a SWOT analysis.

Table 2-5: E-waste SWOT Analysis

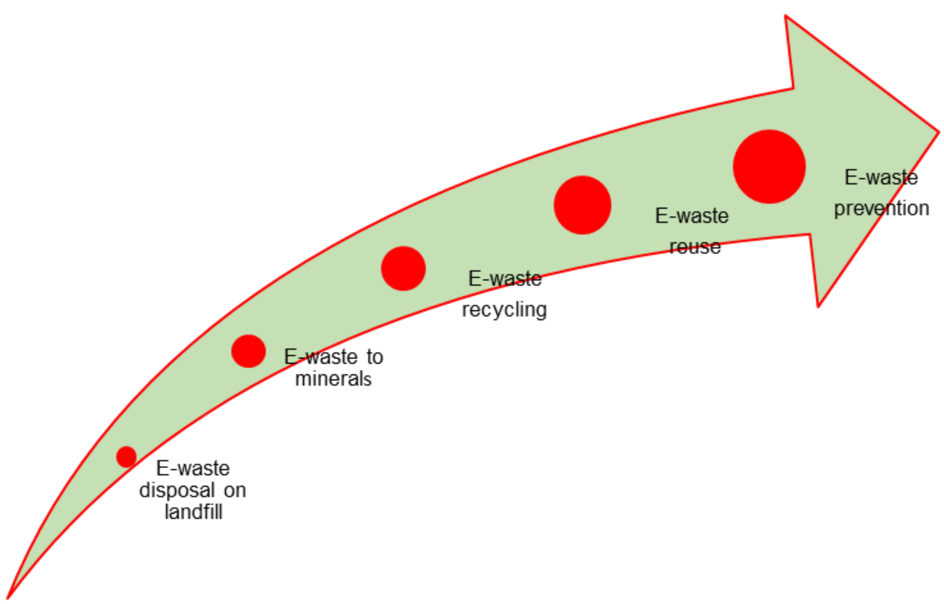
| STRENGTH | WEAKNESSES | OPPORTUNITIES | THREATS |
|---|---|---|---|
| Recycling of e-waste leads to the recovery of valuable metals.<br><br>Employment creation in the recycling industry<br><br>Donated near obsolete electrical and electronic goods help modernize people. | Zimbabwe has a haphazard, waste management mechanism with more than one government arm and department dealing with its management. This means there is more than one law dealing with waste management.<br><br>Zero national policy on e-waste<br><br>Poor technological abilities to process or recycle e-waste<br><br>Waste separation is not done in Zimbabwe properly<br><br>There is no proper landfill in Zimbabwe<br><br>Waste collection is poor if any as roadside dumping in the residential areas is an obvious site | Recovery of valuable minerals from electronic waste such as Gold, Iron and other metals<br><br>The recycling of e-waste creates employment for those who will be picking the e-waste, the people working in the processing workshop and transportation of such.<br><br>The opportunity to recycle e-waste means there will be environmental protection, and public health is also protected with proper management of e-waste. | Heavy metals in e-waste have serious effects on both the environment and public health as this can cause cancer and other critical problems.<br><br>Zimbabwe no legal instrument of e-waste to protect the environment and human health.<br><br>The environmental institutions available cannot deal with e-waste management.<br><br>There are large volumes of obsolete electronic waste in Zimbabwe<br><br>There are no collection mechanisms of e-waste, no proper recycling facilities and technologies.<br><br>No legal instruments are handling the production of electronic goods and importation of electrical gadgets. |

Source: Adopted from Nartey, K.V. (2016)

The e-waste which in some instances is called e-garbage, e-scrap, e-rubbish or simply electronic waste has according to Oteng- Ababio, (2012) become an emerging challenge as well as a business opportunity of tremendous significance. This means that the poor marginalized in developing countries using primitive recycling methods for e-waste are at risk (Seligson, 2013). The developed world using modern metallurgical facilities have very little exposure to heavy metals in e-waste. This is why Balde, *et al.,* (2014) indicated that the resource potential of recyclable material commonly called the urban mine and similarly the hazardous material called the toxic mine.

The common waste management hierarchy in Figure 2.12 above shows that little waste must be deposited at landfills and the rest be recycled and most importantly avoided where possible. The tail of e-waste management below in Figure 2.13 shows that e-waste management just like all other forms of waste should be avoided and this may mean coming in of other forms of technology that does not use dangerous substances in the production of electrical and electronic goods such as the elimination of mercury in fluorescent tubes and other eco-friendly of green technology basically to eliminate heavy metals and ensure that the management of e-waste if best. Critical in the e-waste management tail below is the extraction of valuables from e-waste which is currently called urban mining.

Figure 2.13: E-waste Management Tail



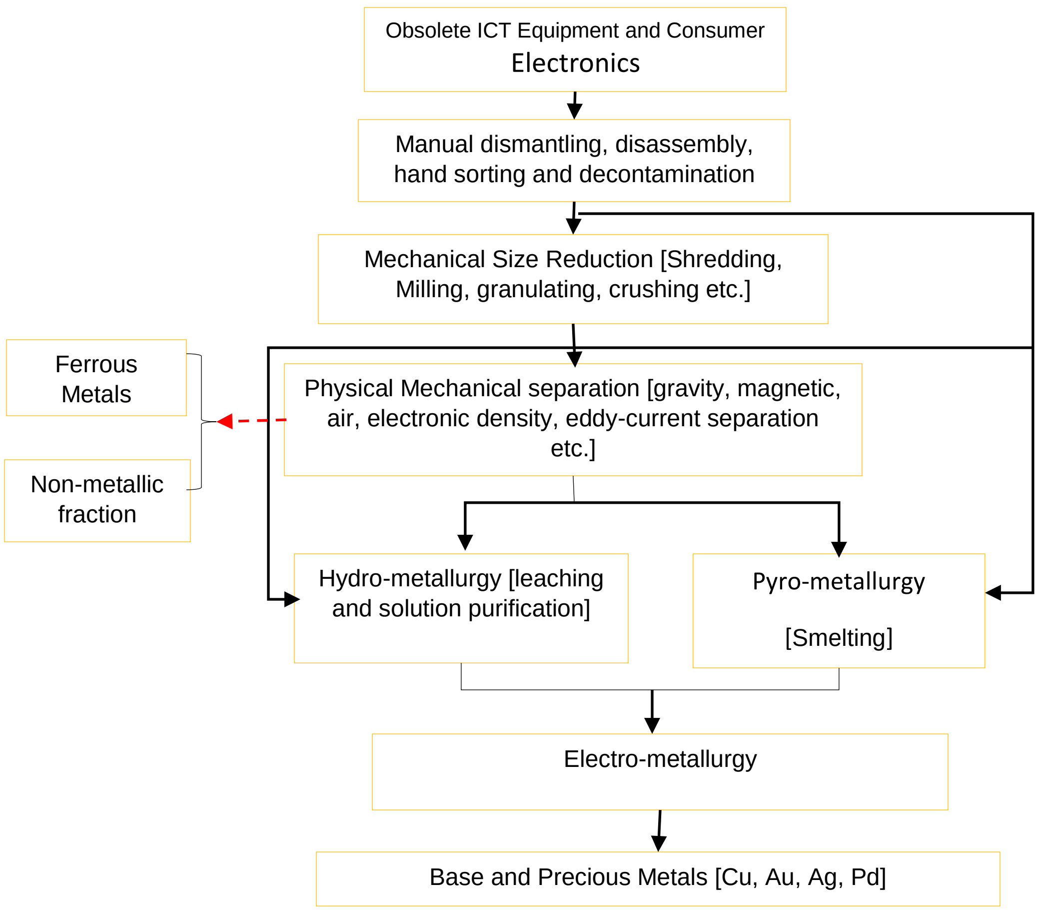

Source: Survey, (2019).

The principle of urban mining is based on the notion that millions of dollars in the form of gold, silver and other precious materials are buried in landfills and dumpsites (Okwu and Onyeje, 2014) yet these can be recovered. Okwu and Onyeje, (2014) indicated that e-waste contains precious metals whose deposits are 40 to 50 times richer than ore mined from the ground, hence the need to invest in urban mining as this can help developing countries benefit from e-waste which is seemingly being dumped on them by developing countries, yet they cannot deal with its management and thus exposing the environment and human health to the effects of heavy metal pollution. There are several e-waste handlings and recovering processes.

E-waste consists of a broad range of other materials such as glass ceramics, plastics and rubber, rare earth, non-ferrous metals. Aluminium, copper and lead, ferrous metals, steel iron and other precious metals (platinum group metals, gold, silver (ILO, 2012). Older e-waste often contains more hazardous compounds than recently produced waste (Mundi, 2010). These are obtained through various means with the developed countries with better methods and developing countries with primitive and rudimental methods. In LMICs Pyro, hydro and bio metallurgical processes are commonly used to recover valuable metals (Cui and Zhang, 2008). E-waste recycling requires large capital investments, qualified and well-educated employees and high quantities of e-waste. This probably explains why urban mining and recycling of e-waste has not been taken seriously in developing countries and has been left to informal waste workers and small-scale recyclers. The individuals who are recycling e-waste in Harare, Zimbabwe are just taking it as part of some scrap metals that they recycle and others for other uses like taking what is perceived to be parts that can be used in repairing other problematic e-good to which the owners still feel they need and can use them more.

With recycling in developing countries like Zimbabwe most of the people involved in recycling e-waste do not use protective clothing. Moreover, they use primitive ways of dismantling such e-waste such as burning it to retrieve certain aspects they need. E-waste from various obsolete gadgets is harvested from various e-wastes. This obsolete e-waste is dismantled and sorted. The sorted stuff is then shredded into smaller aggregates whose size is optimum for physical and mechanical separation through various ways, such as gravity, air density and electronic separation as well as winnowing. The electronic waste can be processed to return valuable metal such as gold and others. The valuable stuff is then exposed to hydro-metallurgy, pyro-metallurgy and electro-metallurgy processes to liberate the gold and other important material from the chaff. Pyro-metallurgy involves the crushing of gold encompassing scrap and blaze them at elevated temperature by smelting in a plasma arc furnace to recover gold and other critical products. Figure 2.13 below explains the processes of recovering important metals from e-waste.

Figure 2.14: E-Waste Handling and Recovering of Critical Components




Source: Lydall, Nyanjowa and James, (2017).

Hydrometallurgy uses water to attract hydrophilic materials and repel hydrophobic materials. This usually happens by adding reagents to induce such reactions. In some instances, water is used in gem stables and spiral separators to separate wanted material through gravity. It must however be noted that retrieving gold from e-waste involves cyanide which again is dangerous to the environment and human health. Cyanide is used to regulate pH to 9 - 11 to ensure that activated carbons attract gold.

Pyrometallurgy involves the use of fire or heat to smelt crushed e-waste and blaze it at elevated temperatures in a plasma arc furnace or blast furnace to recoup gold from e-waste. Pyro-metallurgical includes incineration and smelting of e-waste to get valuables such as gold silver and copper, because resources are scarce especially in LMICs these absolute Pyrometallurgical methods are applied using emission filters or emission control system, leading to the release of toxic components such as polycyclic aromatic hydrocarbons (PAHs), halogenated hydrocarbons into the environment as aerosol particles. Thermal treatment and combustion process widely used in the primitive process generates toxic chemicals such as Polychlorinated Dibenzodioxins and Furans (PCDD/Fs)

Hydro and bio-metallurgical processes are used to dissolve and recover the target metals, hydrometallurgy processing acids, chemicals like cyanide, halide, thiourea and thiosulphate are used and Bio-metallurgical processing microbes, pyretic compounds, oxygen and water are used to accelerate the natural leaching process of metals from e-waste heaps (Leung *et al.,* 2008).

Heavy metals, metalloids, halogenated hydrocarbons and other persistent and hazardous pollutants are to be found in e-waste this means, while the effort to recover critical metals is done, there should also be efforts to manage any waste that come along with such processes as these are dangerous to both the environment and human health.

## 2.16 INCINERATION OF E-WASTE

According to Khopande, (2012), this is a controlled and complete combustion process in which e-waste is burnt at a very high temperature of 900 to 1000 degrees Celsius. The emission and ashes from the burning of e-waste especially PVC and brominated flame retardants in wire insulation contain brominated and chlorinated dioxins which are deadly persistent organic pollutants (POPs), cancer-causing polycyclic aromatics hydrocarbons (PAHs) are also present in the ash and emissions Khopade, (2012).

Heavy metals are emitted into the atmosphere and change into slag and exhaust gas residues and can reenter the environment. It must however be noted that according to

Lombard, (2009) indicated that unrefined e-waste dumped on landfills does not put much of a risk.

## 2.17 SUSTAINABLE E-WASTE MANAGEMENT PRINCIPLES

Deploying various strategies to control e-waste is referred to as integrated e-waste management. The burning of such waste, its illegal dumping and emission from waste disposal contribute to dioxin, chlorinated organic component and heavy metal in the atmosphere. They all are persistent and have a tremendous impact on global warming and bio-contamination of the biodiversity (Christensen, 2011). Several principles are critical in the management of e-waste in both developing and developed countries. These principles are discussed in Table 2.6 below.

E-waste management should be a priority and hence principles of waste management as indicated by the ILO, (2007) should be applied in its management. These principles include polluter pay, cradle to grave, precautionary, producer responsibility and integrated waste management principles. In the case of electronic waste, the principles highlight the need to monitor electronic goods from the date of manufacturing up until that product life cycle has ended. This is to ensure that it is taken back for proper management as waste. However, in cases where individual polluters are identified the polluter pay principle must apply. The general assumption is that very little e-waste should be disposed of. However, where disposal takes place, serious treatment should be done before disposal to avoid heavy metal pollution into the environment. Green computing should be encouraged to reduce possible environmental and health problem when such products are discarded into the environment and around people. Figure 2.12 below shows the best ways to deal with e-waste if its dangers are to be reduced. The best solution is to avoid the use of dangerous substances in the production of electronic good. It must, however, be noted that it is difficult to avoid the use of dangerous substances in the production of electronic good and as such, reduction and recycling remains the only solution.

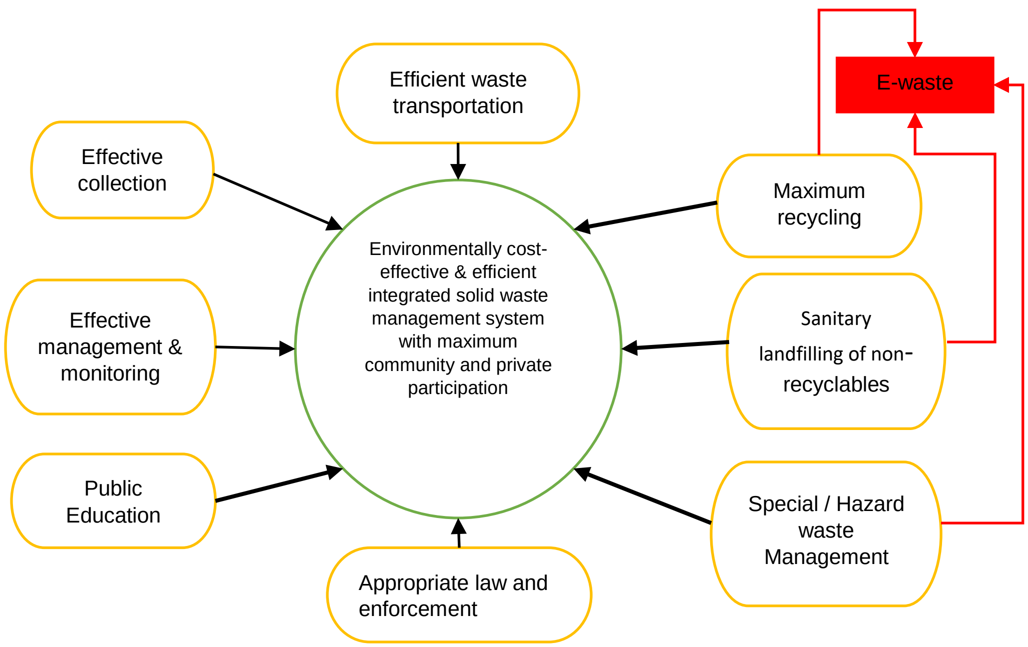
Table 2-6: Principles of Waste Management

| PRECAUTIONARY PRINCIPLE |
| --- |
| Oteng-Ababio, (2012) state that man has always been a proficient producer of waste, however towards the end of the 20th century there has been an upsurge of new noxious clutter. This is what has given birth to the precautionary principle in waste management. This entails that the handling of waste that is not known in terms of toxicity should be treated with care as a mere assumption and subsequent wrong classification of dangerous waste may cost the environment and human health, as such precautionary measures must be taken to avoid potential pollution. The dangers that come with e-waste are varied since it contains various heavy metals that are dangerous to the environment and human health and because of this e-waste should be cautiously treated to avoid situations where dangerous substances are mistaken for non-hazardous waste. |
| CRADLE-TO-GRAVE PRINCIPLE |
| The 'hyper-technology that is hailed as a crucial vector' for future modern development has a not-so-modern downside to it as electronic waste is a threat to the environment and humanity, and as such the Cradle to Grave concept, is revolving around the wheel of life e-waste cycle whose emphasis is basically on the management of e-waste from the day it is manufactured as new a product up until its discarded. The thrust of this principle is on the availability of environmental legislation that compels producers and consumers of electronic goods to each have a responsibility of ensuring that electronic goods that are absolute are returned to their producers so that they can be recycled.<br>The 'cradle to grave' principle directs the proper handling of e-waste from the place of generation to the final place of disposal (the grave). This means that the management of e-waste starts when an electronic good is produced and labels about its dangers to the environment as well as its disposal showed. This principle also calls for close cooperation between the producer of electronic goods, the consumer and the disposing authority. |

| |
|---|
| DUTY OF CARE PRINCIPLE EXTENDED PRODUCER RESPONSIBILITY. |
| This concept gives the manufacturer of electronic goods the responsibility of ensuring that electrical and electronic goods are managed from cradle to grave. This means that at the production of an electronic good the producer of that item assumes the responsibility of ensuring that wherever it goes it will be absolute by such a time and therefore the producer has a responsibility to call it back and ensure that it is recycled properly. The duty of care principle also applies in the management of electronic products from the date of production to the final destination, because the customers of given products should be able to assist in the management of waste. This goes hand in glove with environmental education to members of the public because this teaches people to be responsible about e-waste issues and encourage them to practise the precautionary principle and advocate for the treatment of waste whose toxicity is not known before they are disposed, to ensure that no mistakes are made. |
| LIFE CYCLE PRINCIPLE |
| Products should be designed, produced and managed in a manner that is critical to environmental concerns which are factored in and accounted for to reduce or to eliminate e-waste associated harmful substances during generation, use, recovery and disposal. The lifecycle principle demands proper management of products from the date of manufacturing up the ladder until the end of a product's life. This means that to reduce waste the products should have minimal toxic substances and customers should be educated on how to dispose of these at the end of life of the product. For example, in some cases, bulbs that are free of mercury are produced and this means an action has been taken at the first stage to ensure that no mercury is deposited into the environment via bulbs. |
| INTEGRATED WASTE MANAGEMENT |
| The crux of this principle is based on the fact that e-waste generation should be minimized or avoided as much as possible. This is a concept that sees the environment as something that must be protected by avoiding pollution. This is an internationally accepted approach used to manage waste. The recycling and reusing of waste, in this case, e-waste management should be employed whenever possible. E-waste that |

cannot be recycled or reused must be treated or compacted to reduce toxicity and volume. Any waste that cannot be subjected to the above should be disposed of, in properly designed and managed landfills. The integrated approach entails the inclusion of aspects that are indicated in Figure 2.15 below.

Figure 2.15: Integrated Waste Management Mode




Source: Adapted from Mandevere, B. (2016).

The integrated approach if well implemented will ensure that e-waste generation is minimised, and recycling and reusing are upheld. This will also see to it that waste is treated and properly disposed of in proper landfills. The integrated waste management approach is, therefore, the ideal situation in the management of e-waste because it is an all-stakeholder participation approach; this approach has been employed in several developed countries and has been a success. It is therefore advisable for developing countries to follow the same e-waste management development path.

| POLLUTER PAYS PRINCIPLE |
| --- |
| The concept is applied to make the generator of waste pay for problems caused and thus in this case it relegates the responsibility of managing e-waste to the polluter. This principle says the polluter should pay for the pollution they cause. This is however a disadvantage in some cases as some polluters would prefer to pollute and then pay. Consequently, some developed countries pollute the environment of the developing countries through transnational companies and then simply pay for the pollution they would have caused. This brings back the concept of the haves and have not's and the ultimate environmental pollution in developing countries since they may take the money and use it for other critical economic issues and sacrifice the environment.<br>There is also the polluter pay principle which is responsible for ensuring that individuals and institutions that pollute the environment pay for their pollution and also compensate affected parties. This concept is defeated by international trade which has seen the developed world donating and dumping in the developing world electronic waste in the name of bridging the electronic divide. Besides this, it is difficult for e-waste producers in the developed world to follow their product in the developing world when they become obsolete. Unless they establish collection points that are uneconomic in most cases, it cannot be done. Added to this, the lack of legislation to control e-waste in developing countries makes Africa a convenient dumping site for them. |

Source: Adapted from ILO, (2007)

## 2.18 ZIMBABWEAN WASTE POLICIES AND LAWS

The outdated and poorly enforced environmental legislation with no set standards has been complicating waste management in Sub-Saharan Africa (SSA) (Achankeng, 2003). This is even serious with the lack of legislation that is specifically directed towards the management and handling of e-waste in these developing countries (Achankeng, 2003). Zimbabwe has more than four legal instruments aimed at ensuring proper waste management. These include among others the EMA, Water Act (Chapter, 20:22), Public Health Act (Chapter, 15:09) and others. However, be this as it may, Maseva, (2005) indicated that Zimbabwe still has a long way to go regarding waste management and this includes electronic waste as e-waste management is yet to be fortified by a legal instrument in Zimbabwe.

Tevera, *et al.,* (2002) indicated that a lapse in the management of waste in Zimbabwe is a product of poor legislative implementation. This is further catapulted by the current wave of e-waste which is very harmful to both the environment and human health. Zimbabwe as is evident still must seriously deal with e-waste management and if possible, craft a legal instrument specifically for e-waste as well as domesticating the Bamako and Basel Conventions. Section, 73 of the Zimbabwean Constitution gives people the right to a clean environment (Mandevere, 2016). This means that as electronic waste is said to be seriously threatening the environment and humanity, it is important to come up with management mechanisms that will ensure that the effects of e-waste are minimised.

### 2.18.1 Environmental laws in Zimbabwe

Zimbabwe's environmental management issues are largely administered and managed by the ZEMA, a statutory body whose primary mandate is to implement the country's EMA. Other legislation that has a bearing on environmental issues include the Public Health Act 15:09, the Water Act 20:22, Urban Council Act 29:15 and the Regional and Town Planning Act 29:12. However, according to Magadzire and Maseva (2006), these are administered and managed by different government departments. This differentiation has resulted in duplicated policy implementation as the authority of government departments tends to differ even though they perform the same functions (Mandevere 2016, pp: 4). The laws' years of adoption, as well as the department or ministry administering the acts, are tabulated below on Table 2.7.

Table 2-7 : Zimbabwean Waste Management Legislation Adoption

| **WASTE ACT LAW** | **DATE OF ISSUE** | **SUMMARY OF THE ACT** |
|---|---|---|
| Environmental Management Act ***[Chapter 20:27]*** Zimbabwe | 2002 | Handles the concept of Integrated Environmental Management (IEM) through the EMA. The act aims to promote sustainable management of Zimbabwe's natural and physical resources (Naome *et al.,* 2012). The Act was designed to give credence to the concept of "intergenerational equity" as enshrined in the Brundtland Commission' definition of sustainable development. |

| | | |
|---|---|---|
| Environmental Management Agency/Ministry of Environment, Climate and Water | | According to Chinamora (1995) before the coming in of EMA Zimbabwe's environmental legislation was contained in more than 18 different statutes and administered by 8 different ministries.<br>The act does not allow the population to dispose of waste and pollutes the environment affecting the people's health thus **Section 69.** While this is the case **Section 83** discourages illegal dumping on the roadside, streets and open land and encourages recycling and waste minimisation in **Section 36.**<br>The act has other statutory instruments that help in environmental management and of note is SI **10 of 2007** which demand that generators of hazardous waste should develop a waste management plan which should include an inventory of hazardous substances thus their quantity and composition. |
| Water Act<br>***[Chapter 20:22]***<br>Ministry of Water Resources / ZINWA Zimbabwe National Water Authority | 1996 | This law looks at critical issues to do with water management and water rights. **Section 91** looks at water pollution, discourages the disposal of organic or non-organic matter into the water to cause pollution. **Section 94** demand that local authorities report if they believe that an offence has been committed in the form of pollution. The local authorities are responsible for controlling pollution of public, private and underground water. This is not the case with Harare as the local authority is failing to manage its waste thus resulting in illegal dumping of e-waste and other forms of waste thus polluting the environment to include critical water sources for Harare. The act also deals with the controlling of waterworks and borehole drilling. |
| Public Health Act<br>***[Chapter 15:09]***<br>Ministry of Health and Child Welfare | 1924 | This deals with public health issues and ensures that the public is protected. The act demands that all local authorities should be responsible for the management of the waste generated within their area of jurisdiction. **Section 83** indicates the need to take all lawful, necessary and reasonably practical measures for ensuring a clean environment with no accumulation of waste which may be harmful to its population such as e-waste in this case. |
| Urban Council Act<br>***[Chapter 29:15]***<br>Ministry of Local Government and National Housing | 1995 | The act talks of removal and disposal of refuse and other unhealthy matter. There is also a provision for the collection, removal and disposal of such. The disposal aspect is however not defined just like what e-waste is and how it should be treated and thus regarding e-waste as any other household solid waste yet this is one form of waste that is currently causing problems to local authorities across the globe. |
| Regional Town and Country Planning Act<br>***[Chapter 29: 12]***<br>Ministry of Local Government and National Housing | 1976 | Provides for the planning of the region, districts and local area. The planning of such is aimed at ensuring that the physical environment is protected and particularly by promoting health, safety and amenity. **Section 22 (C**) also is about the control of the deposit of refuse and waste materials on land. The Act does not mention e-waste and other forms of waste. This is a testimony that the law is outdated. E-waste that was insignificant at the time the law was passed has overtaken this Act. |
| Rural District Councils Act **[*Chapter 29:13]***<br>Ministry of Local Government and National Housing | 1988 | The act talks of waste by indicating that councils should provide sanitary convenience on land under their control to ensure effluent or refuse removal and treatment. **Section 32 (1)** talks about providing and operating a service for the removal and treatment of effluent. The act generalises waste and does not specify electronic waste in particular. This means e-waste is treated as any other form of waste. The treatment of waste seems to talk of other forms of waste that are not e-waste as the councils cannot treat such. |

Source: Primary Data, (2019).

Despite the above-indicated legislation, other legal instruments try to address waste management in Harare. These are the Harare Waste Management By-law (Statutory Instrument [SI] 477 of 1979), Harare Waste Management Amendment By-law (SI 127 of 1981) and Harare (Anti-litter) By-law (SI 185 of 1981). In addition to these Harare by-laws, Zimbabwe has other policies that also attempt to deal with waste management. These include, among others, the Draft National Environmental Policy (DNEP), Environmental Impact Assessment Policy (EIAP) and the Zimbabwe National Sustainable Strategy (ZNSS) (Ministry of Environment and Tourism, 2002). Despite the legal instruments listed above, the Ministry of Environment and Tourism (2004) indicated that Zimbabwe does not have an overall waste management policy and this is a contributory factor to the crisis in the waste management sector in most of its urban centres, Harare included (Makuku and Masiye, 2010).

Magadzire and Maseva, (2006) also indicated that waste management seems to be a challenge, a situation that has been exacerbated by inadequate enforcement rather than the absence or ineffectiveness of national legislation governing waste management. Tevera *et al.,* (2002) also share the same sentiments that poor legislative implementation results in illegal dumping. Senkoro, (2003) and Kidd, (2009) also agreed with the point that ineffective enforcement of these instruments leads to environmental and health problems. This is clear and is a complex challenge as e-waste has not been attended to by any one of the legal instruments other than it being labelled hazardous waste. Considering the rate at which e-waste is being generated and the failure to manage it, is critical that there be a legal document specifically for the management of e-waste in Harare and Zimbabwe as a whole.

Despite the array of environmental legislation, it is critical to note that Zimbabwe ratified the Bamako Convention but has not domesticated it yet. This means that the environmental laws are available but not critically addressing local e-waste management from an international perspective, exposing the country to poor e-waste management. The laws are administered by different ministries and government departments thus ensuring that members of the public are accorded a clean and habitable environment free of waste-related diseases. The concept of sustainability is a product of these legislations.

Irrespective of the various legislative documents listed above, the Ministry of Environment and Tourism, (2004) lamented that Zimbabwe does not have an overall waste management policy and this is a contributory factor to the crisis in the waste management sector in most of its urban centres (Makuku and Masiye, 2010). Noting the same, Magadzire and Maseva, (2006) also indicated that the poor waste management situation has been exacerbated by inadequate enforcement rather than the absence or ineffectiveness of national legislation governing waste management.

Achankeng, (2003) lamented that outdated and poorly enforced environmental legislation which lacks set standards has been complicating solid waste management in Sub Saharan Africa (SSA). This is pertinent and evident in Zimbabwe where most of the legislation is outdated, such as the Regional and Town Planning Act of 1976 and also the Water Act of 1996. Srinivas, (2003) and Medina, (2010) indicated that multiplicity of cities in Asia and Africa, Harare included, collect less than half of the waste generated and dump the rest in open spaces. This is happening despite environmental laws in most of these countries. This is overwhelming evidence in the form of growing piles of uncollected solid waste that municipalities in Sub-Saharan Africa are failing to keep pace with the scale of urbanisation and the environmental and health associated with it Sonkero, (2003) and Mandevere, (2016). This is worsened by the birth of e-waste under an environment that is marred by a shortage of adequate financial resources which hinders sanitary disposal of solid waste in Sub-Saharan Africa (Macozoma, 2001).

In Zimbabwe, there seems to be a general reluctance by all government departments and agencies to prosecute offenders (Makwara and Magudu, 2013). The pieces of legislation discussed in Table 2.7 above are outdated and fees charged on environmental pollution are very low (Chinobva and Makarate, 2011). The city of Harare has seen according to Saungweme, (2012) burning of waste and thus releasing toxic smoke and harmful substances into the atmosphere.

The problem of waste and e-waste, in particular dumping, has become ubiquitous in major cities of the developing world (Chirisa, 2012). Nhete, (2006) indicated that waste management has become woefully inadequate and illegal dumping seems to the order of the day as the proliferation of illegal dumps is fast becoming the order of the day.

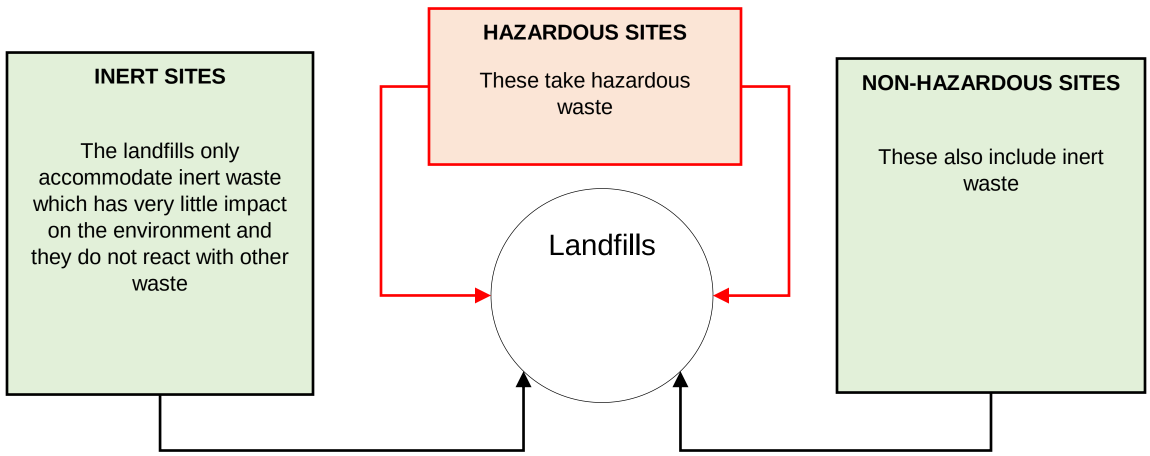
In a nutshell, the Zimbabwean laws regarding waste management and in particular e-waste are not linear, they are rather a diverse aspect whose involvement is multiple in nature with diverse and divergent views and objectives. This makes e-waste management complex as a lot has to be done to ensure a common law of e-waste which is an across-the-board kind of law involving collaboration among government, NGOs, formal and informal players in the field of e-waste management.

It is also important to have an inventory of e-waste in Harare and Zimbabwe in general. This will give a clear picture of e-waste on the ground, hence giving policy direction and formulation. Currently, e-waste issues are based on anecdotal data and evidence, with no inventories on e-waste. Some countries like India endorsed the Basel Convention but did not ratify the Basel Action Network (BAN). There are no e-waste management laws and where they exist, the poor implementation of legal instruments, corruption, absence of a standard for the recycling of e-waste, poor participation of stakeholders in supporting/applying sustainable and more environmentally friendly recycling methods especially in LMICs, only promote the informal recycling of e-waste.

### 2.18.2. Landfills and dumpsites

Most waste including e-waste the world over end-up in a dumpsite or a landfill. This is determined by a multiplicity of factors, one of which is because developed countries have well-established landfills while developing countries like Zimbabwe are still using dumpsites. Harare as the capital city still relies on dumping waste and of particular note e-waste at Pomona dumpsite. The other dumpsite for Harare is the Golden Quarry which is currently not accommodating other forms of waste but hazardous waste only. According to Ezeah, (2010) waste management is affected by poor technology in most developing countries. This notion is true with regards to e-waste management that requires technology to do proper recycling of e-waste. This is complicated by the lack of capacity to manage waste. Landfills can be classified according to the types of waste they receive, and these types are shown in Figure 2.16 below:

Figure 2.16: Landfills and Types of Waste




Source: Survey, (2019).

The above types of landfill sites are critical in the management of e-waste and several factors are considered in the establishment specifically of hazardous sites. These include the distance from residential sites, water bodies, recreation sites, underlying rock and land size and are considered critical factors to selecting a site for a landfill. Geological and hydrological conditions of the area, cultural patrimony of the area, flooding risk and landslides risk in the area are also some of the factors to be considered. These factors, according to Jerie (2005), can be divided into environmental, socio-cultural and administrative factors. The factors are also critical especially with e-waste as the decomposition of such results in heavy metal pollution in the environment and affect human health as well. Environmental Impact Assessment (EIA) and distance from waste generators are also an important aspect when establishing a landfill for e-waste.

According to Jerie, (2005) choice for landfill is a product of a legion of factors. These according to him are environmental, socio-cultural and administrative factors, distance from residential sites, water bodies, recreation sites and other factors. The geological and hydrological conditions of the area, the cultural patrimony of the area, flooding risk and landslides risk in the area are also some of the factors to be considered Environmental Impact Assessment (EIA) is also a prerequisite of the landfill development concept in proper environmental management is to be properly done.

Dariusz, (2003) defines a dumpsite as an area set aside by a local government for solid waste disposal without measures to minimize environmental pollution or limit slope stability. There is no compaction and soil cover on any routine basis. There are no mechanisms and measures to control leachate and landfill gas that is generated in the dumpsites. This is the main source of pollution as underground water and atmospheric air is exposed to such pollution. This situation is catapulted by the coming in of e-waste. According to Jerie, (2005) the Golden Quarry dump in Harare caught fire on 28 August 2000. The fire brigade battled to extinguish the fire for a week. Hazardous substances such as e-waste must have been burning and thus polluting the atmosphere with heavy metals, affecting the environment and posing a health hazard to the residents around the dump.

Taylor and Allen, (2004) write that a dumpsite is the simplest, cheapest and most cost-effective method of disposing of waste. This is so in Harare as the city is still using dumping as a way of managing waste. In most developing countries, almost 100 per cent of generated waste goes to dumpsite (Mandevere and Jerie, 2018). This is against the fact that Allan, (2001) warned that dumpsites will remain a source of groundwater pollution. This means that e-waste is also dumped along with other forms of waste, even though there are so many benefits that come with recycling e-waste than dumping it. The idea of waste dumping is associated with a plethora of health and social effects such as odours, nuisance, ozone gas formation, climate change and other problems and the coming in of e-waste makes the problems even more critical.

## 2.19 E-WASTE MANAGEMENT IN HARARE, ZIMBABWE

Human settlements and Harare, Zimbabwe in particular is facing a catapulted and increasingly complicated and complex as well as formidable environmental problems, particularly because there is little attention being put toward the management of e-waste. A notable problem is the dumping of e-waste all over Harare with visible dumpsites by the roadsides. This shows that e-waste generation has not been matched with an increase in the capacity of the Harare municipality to manage the e-waste, giving rise to disposal problems (Srinivas, 2003). For Harare, e-waste management and disposal seem to be a major challenge in the face of the financial, technical and administrative incapacity of the Harare municipality (Jerie, 2006). Hence the relevance of this study.

Several economic blueprints have been employed in Zimbabwe. These range from, the Economic Structural Adjustment Programme (ESAP), Zimbabwe Programme for Economic and Structural Transformation (ZIMPREST), Short Term Economic Recovery Plan (STEP) 1 and 2, Zimbabwe Agenda for Social Economic Transformation (ZIM ASSET), and most recently, the Transitional Stabilization Programme. These government of Zimbabwe economic development plans are aimed at economic emancipation and liberation. However, while these economic initiatives will contribute to the generation of waste and e-waste once the economy begins to respond to them, environmental protection, especially e-waste initiatives are not yet the government's priority. It is because of this, that the strategies employed in the management of e-waste in Harare are concerning, especially so, given that quantities of e-waste are on the rise and may increase fourfold by 2025 (World Resources, 1996).

It is estimated that up to 5.5 million people are at risk of death from diseases that are a result of poor household solid waste management, including e-waste (Hardoy, *et al.,* 2001). These problems and diseases can be avoided if proper e-waste management strategies are put in place (Zerbock 2003). Harare, the capital city of Zimbabwe, is prone and subject to these ever-multiplying e-waste management problems. Most of the challenges normally faced by cities in developing countries in managing e-waste have to do with some factors which include among others lack of financial capacity, technical expertise, limited environmental education and increased population numbers. One may inevitably conclude that the Harare City Council may therefore be facing the same e-waste management challenges.

Strategies have been traditionally recommended for e-waste minimisation and these are part of the waste management hierarchy and involve reusing, recycling, reducing, avoiding and landfilling. The effectiveness of these conventional waste management strategies is questioned as a multiplicity of e-waste is seen on roadsides dumps and the city of Harare itself confirms they do not have any management options in place as they regard e-waste as any other form of solid waste.

Poor e-waste management in Less Economically Developed Cities (LEDCs) like Harare is a product of a multiplicity of factors; and these include among others deteriorating infrastructure (Machivenyika, 2012), little environmental education among the general populace, increased urbanization and industrialization, too many persons per dwelling, and cultural and personal attitudes (Chirisa, 2012). Past studies by Maphosa and Maposa (2020), HeeKs *et al.,* (2015) and others indicated that existing economic and political conditions affect e-waste management efforts (Zerbock, 2003). These and deteriorating economic and political situation in Harare call for the need to audit the e-waste management efforts of the City Town Council. In Harare, the lack of technical knowledge among municipal workers and environmental knowledge by residents of Harare as well as a failing economy, are affecting e-waste and household solid waste management (Chirisa, 2012).

Population growth has a bearing on the generation of e-waste in Harare. This is because the bigger the population the larger the amount of e-waste generated. Saungweme (2012) argues that population explosions are often associated with increased electronic and electrical product consumption which subsequently leads to e-waste management problems. This is because, in most cases, local authorities fail to employ proper and efficient waste management strategies that are commensurate with the rate of waste generation that an increase in population brings about. This is also supported by Zerbock (2003) who reports that “in many LEDCs such as Zimbabwe, Zambia and other countries like them, an increase in population is not matched with an equal increase in revenue for local municipalities to undertake proper waste, let alone e-waste, management”. It is in the light of this that a proper assessment of the existing approaches for e-waste management was deemed fitting.

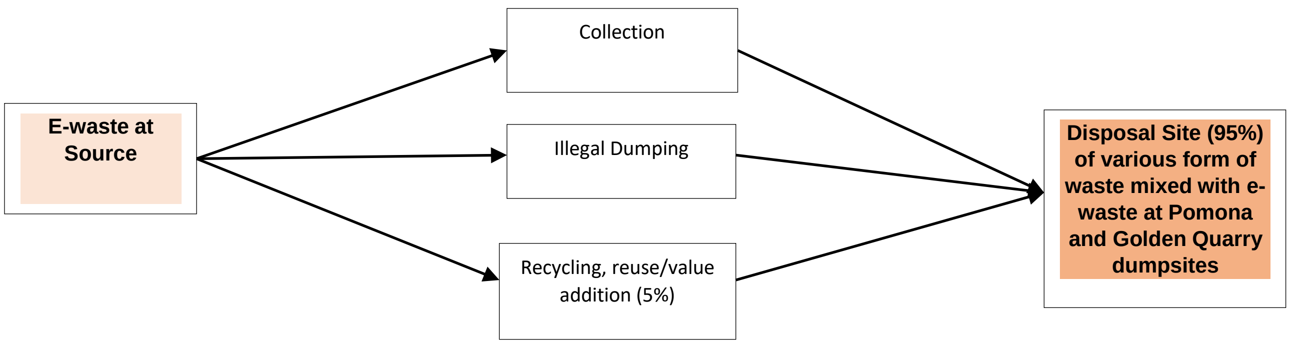
A cursory observation of the economic activities in Harare reveals that a multitude of organisations operating in the city generate electronic waste. Despite doing so, these institutions do not have e-waste management departments in place. This compromises e-waste management as the amount of e-waste generated in a city such as Harare is likely to be proportional to its population. As such, effective e-waste management is not just about population growth but also business entities and their activities, the producers of electrical and electronic goods, sellers, importers and related contributors to e-waste.

The introduction of the Integrated Product Policy (IPP) to ensure that producers produce their products in an environmentally friendly manner (SEPA, 2005) is very critical in the management of e-waste. This is, however, a different situation in developing cities like Harare where the process of e-waste management is negatively affected by several challenges as indicated by Katyal and Satake, (2001). Legislation such as the EMA, city by-laws, and environmental campaigns such as the Presidential Clean-up, “Bin It” campaign, and environmental education and other strategies have been used to manage waste in general in Harare. E-waste remains a problem as evidenced by its continuous accumulation on street sides. Despite the availability of these legislative tools, e-waste management remains a major concern in Harare. E-waste is being treated like any other waste in general thus forgetting the dangers of it on the environment and humans. The presidential clean-up campaign being done once a month in Zimbabwe at the moment is silent on e-waste and generalises waste. The talk is just a clean environment, they do not separate the waste and do not talk of waste separation.  Briefly, e-waste management requires more than just clean up campaigns. There is, therefore, a need to evaluate available waste management strategies with the dangers of e-waste in mind.

Makwara and Magudu (2013), argue that the electronic revolution, as well as other technological advancements, have also contributed to the increased burden of e-waste management challenges. The poor revenue base for municipalities has not made things easier. This situation seems to have led to a fall in the standard of waste management with town councils failing to regularly collect waste around their areas of jurisdiction as scheduled (Makwara and Magudu, 2013).

Katyal and Satake (2001) indicated that financial, technical and material resources are limited in developing cities such as Harare. Consequently, e-waste management is less effective resulting in serious environmental problems. The basis of the process of e-waste management in Harare shows that the greater part of e-waste is dumped along with other forms of waste at the official dumpsite as shown in Figure 2.17.

Figure 2.17: E-Waste Management in Developing Countries




Source: Adapted from Mandevere, (2016).

Building and operating sanitary landfills and incineration plants for e-waste require huge investments and incur substantial operation and maintenance costs. Makwara (2011) reports that the lack of capacity to manage e-waste by the authorities is a visible and pressing urban environmental problems. Demographic changes and economic growth are also a factor that contributes to the generation of e-waste. This becomes a serious issue in Harare, Zimbabwe as e-waste management has virtually collapsed.

The Harare city council is still dumping e-waste at Pomona dumpsite because they do not have the proper technical abilities to handle e-waste of any sort. They also have weak budgets that they cannot even import or invite technical skills from developed countries such as Switzerland to provide technical advice. Due to insufficient funds, Harare municipality cannot finance adequate levels of service especially for low-income people living in the middle and high-density suburbs (Chinobvu and Makarate, 2011). This explains why 95% of waste is dumped at the dumpsites as shown in Figure 2.17

above and as little as 5 % is recycled. The 5% recycled waste is wholly the responsibility of scavengers and other small recycling companies.

Jibril, *et al.,* (2012) indicated that very few urban areas in the developing world have adequate and sustainable waste disposal systems. E-waste is a growing urban problem that has not received much attention in Sub-Saharan Africa and this has manifested in Harare, Zimbabwe. The complexity of e-waste management unfolds due to increasing urbanization which is very visible in Harare. This makes most developing countries home to e-waste. In fact, in Harare areas with poor light access, highways, alleys and areas with unoccupied properties are prime common targets of illegal dumping.

## 2.20 SOURCES OF E-WASTE MANAGEMENT CHALLENGES IN ZIMBABWE.

Zimbabwe is a developing country that is marred by a lot of problems that militate against proper electronic waste management. These problems include among others, the absence of legislation concerning e-waste management. The all-encompassing EMA is notably unclear regarding e-waste and its management. This is perhaps due to the perception that the current rate at which e-waste is being dumped onto the environment is gradual, and therefore not yet harmful. It is difficult to quantify the volume of e-waste generated in Zimbabwe and Harare in particular. Zimbabwe has no policy or legislation on e-waste. Zimbabwe being a developing country depends entirely on imports when it comes to e-products, yet it does not have any legal position on the importation of electronic goods. Katyal and Satake, (2001) indicated that financial and material resources are scarce in developing countries, thus affecting waste management. This situation has been worsened by the emergence of a new challenge in the form of electronic waste. This, therefore, means that a lot must be done to prepare for a future dominated by e-waste.

Makwara and Magudu, (2013) highlight that "prior to the withdrawal of external aid, local authorities tended to over-rely on external technical, material and financial assistance". This is a clear indication that the management of e-waste is marred with a lot of problems and these are worsened by the fact that the developed countries who are supposed to be the source of technical and financial assistance are the ones responsible for the largest amount of e-waste in developing countries if not all.

However, it remains to be known how such challenges have impacted e-waste management practices and to what extent. Such an audit assist in establishing vital considerations in crafting a feasible e-waste management model that is the focus here.

## 2.21 CHALLENGES OF WASTE MANAGEMENT IN CITIES OF DEVELOPING COUNTRIES.

Several studies are pointing to the problem of e-waste management across the globe as capacity is lacking in developing cities like Harare. This has seen e-waste becoming the most visible, challenging and pressing urban environmental problem. Harare as aptly presented by Nhete (2006) who argues that in most cities in developing countries waste collection has virtually collapsed and has given birth to chaotic and rampant illegal dumping. This has been a common problem in most developing countries.

Chidavaenzi (2006) also indicated that until the mid-1990s Zimbabwe’s urban centres were regarded as models of cleanliness in Africa and beyond. However, the economic melt-down and the coming in of e-waste due to the electronic revolution coupled with the unavailability of fuel, frequent breakdown of waste collection vehicles, lack of technology to recycle e-waste are the challenges that have resulted in poor waste management. This explains why Makwara and Magudu (2013) reported that Harare municipality relied on external aid, and tended to over-rely on external technical, material and financial assistance to manage waste. The current e-waste problem has been made more complex by a melting economy. The donor support has withdrawn due to the political difference between the Zimbabwean government and the donor countries (Machivenyika 2012). The withdrawal by the donors has resulted in a legion of challenges that have militated against sound e-waste management in most cities of the developing world, like Harare in Zimbabwe.

There are several other hazardous components of e-waste such as antimony trioxide, selenium, chromium, manganese, polyvinyl chloride (PVC plastics) and cobalt and polybrominated flame retardants (STEP, 2009). These cause health hazards to human beings and the environment (Machivenyika, 2012; Chinobva and Makarati, 2011). This situation generates health hazards and causes environmental pollution especially as a result of heavy metals which when washed into public water cause serious health problems. UNHABITAT (2006) has it on record that less than 20% of urban solid waste, including electronic waste, is collected and disposed of properly. This means that there is virtually little if any collection taking place. As a result, there is serious disposal of heavy metals into the river and other water sources around most urban cities in developing countries like Zimbabwe.

## 2.22 CHALLENGES AND OPPORTUNITIES OF E-WASTE MANAGEMENT

E-waste products have both valuable and non-valuable elements. Valuable elements include gold, silver, platinum, palladium, copper and plastics. Whereas non-valuable elements include toxics which are arsenic, lead and mercury, among others. The toxic substances cause endocrinal disorder, neurological disorders and in some cases cancer (Agarwal, 2012). E-waste is therefore regarded as a mixed bag.

Shifting away from e-waste management to resource recovery is critical however, metal recovery by burning of PVC wires releasing brominated and chlorinated dioxins as well as carcinogenic Polycyclic Aromatic Hydrocarbons (PAHS) into the soil, water and air are rampant in the informal sector. This points to pollution of the soil, water and air which with time gives birth to health problems to the population of a given locality. All of Harare's urban dwellings rely on piped water from dams such as Lake Chivero. The accumulation of heavy metals in water makes water treatment one of the most expensive aspects of urban life and as such a municipal challenge for dams such as the already hypereutrophic Lake Chivero. Prakash *et al.,* (2010) estimated that about 8 000 metric tons of e-waste are being processed annually at Agbogbloshie metal scrap yard. This points to a serious volume of e-waste being produced with obviously serious environmental and public health implications.

E-waste is a form of waste that can be discarded or disposed of with no regard for future use. A rational and persistent proper management however allows for the reaping of a range of benefits. These include economic, for instance, the creation of markets where there are proper treatment and disposal facilities, that yield the recovery of valuables and creation of jobs. This will socially lift the poor cities from poverty as urban mining will go a long way in empowering such.

Pollution and greenhouse emissions will be reduced with proper recycling and reusing. This will create a better environment that ensures an environmental inheritance for posterity. Despite this, in most developing cities like Harare, waste and e-waste recycling is being left to the poor who pick such waste for selling and in some cases for keeping, especially that waste which they consider useful or resalable. It is the unemployed, uneducated poor, vulnerable women and children who are spending time scavenging for e-waste and retrieving its valuable components either for resale or recycling. These end up with different health problems, thus reducing their life expectancy significantly.

Urban mining will go a long way in empowering the poor and developing cities such as Harare. However, be this as it may be, it is only possible if the developing cities have the technology to process e-waste as currently, the process of recycling is still rudimental in nature. The pollution and greenhouse emissions will however be reduced with proper recycling, reducing and reusing, thus creating a better environment that ensures inter-generational equity.

There is also the view that contamination of a river with heavy metals may cause effects on the ecological balance of the aquatic environment. This has the potential of narrowing the diversity of aquatic organisms as the extent of contamination increases, thus compromising the GAIA Hypothesis which regards organism as equal.

In summary, e-waste, as it stands globally, requires that its management be treated seriously. In this regard, Harare should join the international community in managing e-waste. Such management should entail capitalising on the available benefits of e-waste, for example, the retrieval of precious minerals as well as minimising the downside of e-waste.

## 2.23 STRATEGIES TO MANAGE E-WASTE

In recent years, e-waste has become such a serious problem so much so that every year 20 to 50 million tonnes of electrical and electronic equipment waste are generated worldwide (Balde, *et al.,* 2017). This puts human health, climate and the environment at risk. The e-waste state of affairs has resulted in concerted research efforts and the implementation of various models to manage e-waste. Currently, e-waste is managed by employing some principles of waste management such as recycling and reusing. In cases where recycling and reusing are not feasible, e-waste is treated and properly disposed of following the integrated waste management approach to e-waste management. The integrated waste management approach to e-waste management is an all-inclusive method that has effectively helped developed countries such as Switzerland, to manage e-waste and reduce the impact of e-waste on both humanity and the environment. Various other strategies are discussed below:

Life Cycle Assessment (LCA), this tool is used to design environmentally friendly electronic devices by eliminating hazardous elements that are used in e-waste production such as heavy metals. The use of fibre cables in electronics, the elimination of mercury use in bulbs, are such examples. This minimises e-waste pollution and associated problems to both the environment and human health. It is a powerful tool for identifying potential environmental impacts and helps develop eco-design products that are environmentally friendly. It is also a systematic tool to define many environmental impacts such as carcinogenic elements, climate change, ozone layer destruction, ecotoxicity, and acidification from the birth of electronic products to the end of their life and the ultimate disposal. This helps in the management of e-waste as knowledge of various components of electronic products gives suitable management strategies when they become obsolete.

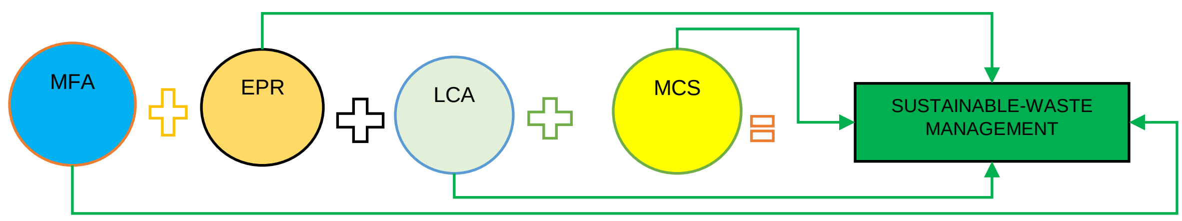
Before the Basel Convention came into force, large volumes of e-waste from developed countries were exported for reuse or recycling in such developing countries as China, India and South Africa. Material Flow Analysis (MFA) is a tool that is used to study the route of e-waste material in space and time. It traces e-waste's pathway from its departure to its final destination. Using MFA, it has been determined that second-hand electronic and electrical goods from developed countries are being used in developing ones.

Multi-Criteria Analysis (MCA), is an all-inclusive management tool that looks at all available management tool and capitalises on the strength of each management to bring about an abject proper management tool. Life Cycle Assessment (LCA), Material Flow Analysis (MFA) and Multi-Criteria Analysis (MCA) are tools to manage e-waste problems and Extended Producer Responsibility (EPR) is the regulation for e-waste management at the national scale.

Extended Producer Responsibility (EPR) gives manufacturers financial responsibility for the entire life cycle of their products especially when they become obsolete. This means the producers of dangerous electrical and electronic products have a responsibility to ensure that their products are responsibly disposed of when they become obsolete. It is however difficult as some of the products are difficult to track and end up being disposed of anyhow.

Optimum e-waste management requires a combination of LCA, MFA, MCA and EPR. EPR may be more appropriate for all countries to minimize the generation of e-waste given that the responsibility for e-waste generated post-Basel Convention is passed back to the producer. It is critical to note that the management of e-waste cannot be a single-handed thing as various factors are at play in different areas and localities of the world. Therefore, an all-inclusive strategy is the best for e-waste management as shown in Figure 2.18, showing the strength of the unified e-waste management tools.

Figure 2.18: Combined E-waste Management Strategies




**LEGEND**

***MFA**: Material Flow Analysis, **EPR**: Extended Producer Responsibility, **MCS**: Multi-Criteria Analysis, **LCA**: Life Cycle Assessment*

Source: Authors own construct, (2019)

It can also be hazardous electronic devices from a complex mixture of metals and components often containing several hundreds of different substances many of which are toxic and create serious e-waste pollution upon disposal. The environmental burden due to the production of electrical and electronic products (ecological garbage) exceeds by far acceptable limits. The main cause currently is e-waste, household solid and industrial waste.

Rich countries dump their old devices in developing countries, sometimes legally as part of philanthropic missions. Sometimes illegally as e-waste, thus liberating themselves from the e-waste disposal problem by burdening the already strained developing countries with more waste. Yet they are already poorly equipped to handle simple forms of waste. It also has become common knowledge that all landfill leaks, even the best 'state of the art' once, are not completely sealed throughout their lifetime. This means that if a landfill leaks in a developing country like Zimbabwe, the outcome is worse as the country is still dumping.

These inappropriate disposal methods of electronic waste fail to reclaim valuable materials and manage toxic materials safely (Kirthik *et al.,* 2017). According to Kiddee *et al.,* (2013), the advent of new design smart functions and technology during the last 20 years has caused the rapid obsolescence of many electronic and electrical products. The lifespan of many electronic goods has been substantially shortened due to advances in electronics, attractive consumer designs, alluring marketing and increasing compatibility issues. The major problem for developing countries arises when they import cheap electronic goods which developed countries would have found to be ecologically unfriendly and so want to be rid of. When the imported electronic and electrical goods eventually become e-waste, it becomes the dilemma of the importing country.

The World Health Organization compiled a list of the 10 major chemicals of concern which include many heavy metals and of note amongst the ten (10) is arsenic, cadmium, lead and mercury (WHO, 2011). These are dangerous to the environment and human health and are more common in e-waste especially if not properly managed. These can accumulate in the environment and living organisms and end up in human beings. Bio-accumulation is the accumulation of substances or chemicals in an organism. There are a small number of plants that easily absorb high levels of metals from the surrounding soils, this is called hyper-accumulation. If these are harvested for human use, exposure happens (Martins and Griswold, 2009). E-waste impact on human health can happen in two ways which are:

(i) Food chain contamination by toxic substances from disposal and primitive recycling processes. The result of which by-products enter the food chain and are transferred to humans. If this keeps accumulating in human beings, it may cause various health problems.

(ii) Heavy metals contamination in the aquatic ecosystem due to discharge of industrial effluent may pose a serious threat to human health (Rai, 2008) and this is why e-waste ending up in landfills are described as toxic time bombs (Sivaramanan, 2013).

Direct impact on workers who do recycling from the occupational exposure to toxic substances. This is very common in developing countries where people use crude ways of recycling e-waste and are not educated enough to know the implications of their way of living.

It is estimated that 80 % of all the e-waste in developed countries is being exported and e-waste disposal methods include landfill and incineration both of which pose considerable contamination risks, landfill leachates can potentially transport toxic substances into groundwater whilst combustion in an incinerator can emit toxic gases into the atmosphere. This research's focus is on cadmium (Cd) Cobalt (Co), copper (Cu), Iron (Fe), lead (Pb) and mercury (Hg). According to Asante et al., (2012) in Ghana for instance blood, serum, hair, scalp hair, human milk and urine from people who lived in the areas with e-waste are being recycled showed the presence of high concentrations of toxic substances.

Even if second-hand electronic goods are usable, their limited lifespan accelerates their descent into e-waste. Subsequently, most types of equipment arriving in Africa can be considered e-waste at its arrival (Wolfe and Baddeley, 2012). They noted that 70% of all imports to developing countries of electrical and electronic goods are waste. Charisa, (2013) and Chitotombe, (2013) indicated that the ICT industry is affected by the globalized phenomenon of consumerism and what one is called 'built-in obsolescence of equipment'. Developing countries have become toxic dump yards for e-waste (Kirthik *et al.,* 2017). Recycling of e-waste can be divided into three and these are tabulated below:

Table 2-8: E-waste Recycling Stages

| | |
|---|---|
| **Disassembly** | Selective, disassembly targeting by singling out hazardous or valuable components for special treatment is an indispensable process in the recycling of e-waste |
| **Upgrading** | Using mechanical processing and or metallurgical processing to up-grade desirable materials content that is preparing material for refining processes |
| **Refining** | In the last step, recovered material is treated or purified by using chemical (metallurgical) processing to be acceptable for the original use. |

Source: Adopted from Osibanjo, (2014).

Osibanjo, (2014) writes that in a bid to cover the digital divide, Africa and other developing regions of the world are currently undergoing rapid advancement in information and communication technology (ICT). Both the African continent and other developing regions are doing so through the importation of second-hand electronic goods. However, when such imports become obsolete or irreparably break down, developing countries do not have the proper infrastructure to manage the resultant e-waste. Currently, most African countries do not have a well-established system for separation, storage, collection, transportation and disposal of e-waste nor the effective enforcement of regulation relating to hazardous waste management. In the majority of cases, e-waste management practices in Africa are unregulated and employ rudimental techniques at best, to manage often dangerous e-waste.

E-waste management is a paradox of some sort as e-waste has both beneficial and harmful effects. Africa is at risk for the sheer volume of e-waste influx in the view of weak institutional, regulatory and technical capacity to handle the problem, and thus may even worsen the already weak municipal solid waste infrastructure as EEE exported to Africa are hazardous with concentrations of heavy metals several folds higher than permissible levels.

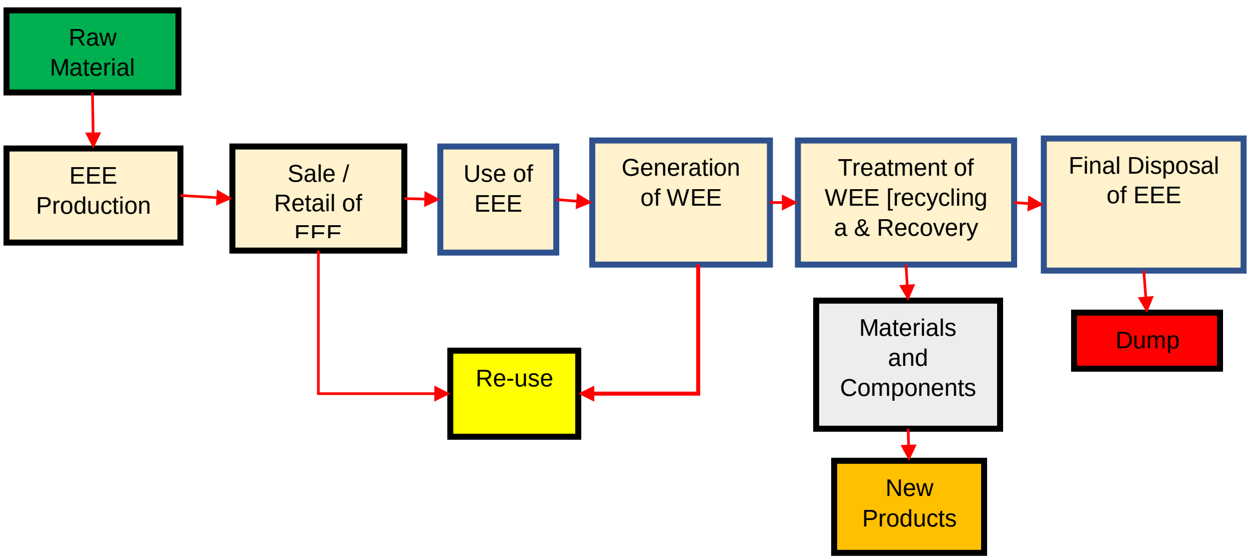
Roven, (2011) reported that growing attention is being given to the impacts of the hazardous components in electronic waste on the environment. The market supply method uses past domestic sales date coupled with the average life of products for a certain. The consumption and use method is based on extrapolation from the average amount of electronic equipment in a typical household. The saturated market method, applied in Switzerland assumes that for each new appliance, the old one reaches its end of life. Currently, the main options for the treatment of electronic waste are reuse, remanufacturing and recycling, as well as incineration and filling. It must, however, be noted that to recover high-value recyclable materials especially in e-waste is very critical although Rajagopalin (2005) believes that recycling is not a solution to managing all forms of waste. Besides, Rajagopalin (2005) also argues that recycling technologies are unavailable if any are primitive in developing cities like Harare.

## 2.24 THE LIFE CYCLE OF E-WASTE

Electronic goods that are produced in various circles of the economy across the globe emanates from various raw materials, which include heavy metals, these are used to produce some aspects of electronic goods of various sorts. The electronic goods produced are sold to consumers locally and internationally by exporting such products. The exporting of electrical and electronic goods is the first stage of broadcasting e-waste seeds because these will then be e-waste after use in the area where they would have been exported to. The cycle is diagrammatically presented in Figure 2.18 below. The electronic goods once sold, starts their life by being used for various purposes and along the way they develop problems leading to them being sold as second-hand electronic goods or being discarded completely as electronic waste.

The electronic waste is then processed to recover critical components, which can be used to produce new products. Other components that are regarded as unimportant will be disposed of at the dumpsite in most developing countries and landfills in the developed countries. The critical path to e-waste management starts when a new electronic item is produced and released into the market where various individuals and companies buy to use such. With time the products become obsolete and they are recycled and important materials are recovered. The recovered materials can be used in the production of new products that will again join the cycle from the cradle to the grave as indicated in Figure 2.19 below.

Figure 2.19: E-Waste Life Cycle



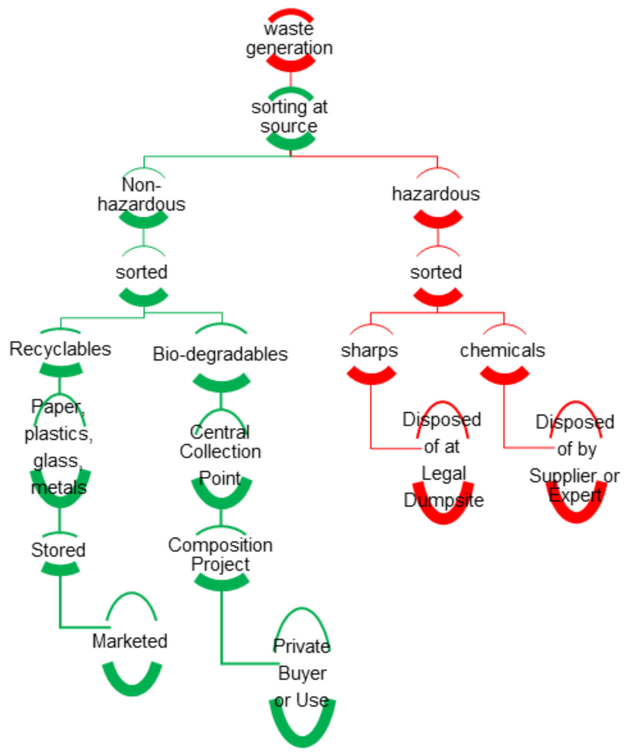

Source: Adopted from UNEP, (2007).

As critical materials are recovered some unwanted materials are treated for disposal as e-waste at the dumpsite as indicated in Figure 2.19 above. It is critical to note that this treatment of e-waste is mostly done in the developed countries than the developing world due to a lack of technology and resources such as financial resources. In the same cycle, some electrical gadgets are reused before being discarded. This in a nutshell simply shows that with technology and recycling facilities in place the e-waste can be managed as there is more to use again than to throw away as e-waste.

## 2.25 SOLID WASTE MANAGEMENT SYSTEM

The management of solid waste varies with the type of waste, amount, available technologies and the knowledge among the population of a given country with regards to the management of solid waste in general. ILO, (2007) gave a detailed solid waste management model to guide various players in waste management. This covers electronic waste as well. Figure 2.20 below shows the model.

Figure 2.20: Solid Waste Management System Model




Source: Adopted from ILO, (2007).

The model show waste in its various forms as hazardous and non-hazardous and others as biodegradable while some are non-biodegradable. Electronic waste is one form of solid waste whose components are hazardous and non-biodegradable and hence the heavy metals that are found in electrical and electronic obsolete goods, if deposited into the environment in large amounts result in its bio-accumulation, thus causing health problems and polluting the environment. E-waste is different from other forms of waste because it releases heavy metals into the environment and causes soil, water and air pollution. Pollution affects people's health. The collection of solid waste for safe disposal is marred with problems such as the absence of waste separation. The failure by authorities and individuals to sort solid waste, to ensure that e-waste is then separated from the rest of the waste and ensure that its management is properly done results in the mushrooming of e-waste dumps which is detrimental to the ecosystem.

## 2.26 HEALTH AND SAFETY IN E-WASTE RECYCLING

Safety issues in the formal or informal sectors of development are topical. The existence of occupational hazards is traced back to "ancient man the hunter and gatherer who became the natural prey of his carnivorous neighbours" (French, 1993). Throughout the history of antiquity, the Stone Age, Iron Age, right up to the industrial era, man has always been plagued by injuries and fatalities (Kotze, 1992). The world has and is developing in several ways to include the electronic revolution and industry 4.0. It is important to note that, to date developing countries are dominated by the informal sector who are into e-waste recycling yet, the workers in this sector are exposed to hazards of all forms and little attention is put to reduce the occupational hazards associated with e-waste recycling. Marginalized population suffer the negative effects of improper e-waste practices. Unsound e-waste management practices in the informal sector of the economy involve hundreds of thousands of poor people many of whom are unaware of the hazards of exposure to e-waste (Niranjani (2014). EEE contains potentially hazardous substances that are generated at recycling. The sources of exposure can be direct or indirect. Direct is when there is skin contact, inhalation or ingestion of hazardous substances or particles (Devin *et al.,* 2014).

Recycling of e-waste is done by the poor and marginalized social groups who resort to scavenging (Devin *et al.,* 2014). While earnings are good the workplace have poor health and safety conditions yet women and child labour are dominant in the e-waste recycling (Davia 2015). Most developing cities like Harare are dominated by an informal e-waste recycling people. According to a report on Indonesian unemployment in 1999 the low-paid urban and rural people moved to informal sector rather than into open unemployment. Like any industrial activity, the informal sector is prone to occupational hazards which expose the informal workers, to risks. The hazards to which the informal worker is exposed are classified by Danton, (1984) as mechanical hazards (which constitute injuries sustained from machinery), biological hazards (which are due to bacteria, fungi and viruses), chemical hazards which are due to (gases, liquids and solids), actually it is estimated that a new chemical is produced in every 15 to 20 minutes averagely in the world. The electronic waste recycling is one of the most lucrative business and those involved are exposed to dangerous substance and heavy metals in their various forms Niranjani (2014). This is so because the people involved do not know what dangers they are exposed to due to the burning of e-waste and ending up breathing the fumes, and handling such with bare hands with no PPE. Exposure to lead dust or fumes leads to the underdevelopment of brain of children, high incidence of skin damage, headaches, hair loss, vertigo, nausea, gastric and duodenal ulcers among children and women in Guiyi, China (Wang *et al.,* 2020).

The level of exposure to hazards in e-waste recycling is not known in Zimbabwe and other developing countries, yet they are indeed working around life threatening hazards in the form of heavy metals which cause cancer and other forms of diseases. The plastics burned at low temperatures during recovery of important parts of the obsolete electrical goods release heavy metals such as mercury and lead affecting children and women who are more active hence more vulnerable. Girls fetch water for boys to put out fire on burning cables as burnt copper wire fetch less money compared to unburnt copper. This does not only affect those directly into e-waste recycling as any harmful residue from e-waste recycling may have second hand exposure or take-home effects as contaminated clothing may affect children at home (Devin *et al.,* 2014).

When e-waste materials are burned during recycling toxic and carcinogenic substances are produced such as dioxins, polycyclic aromatic hydrocarbons. These dangerous substances can be found in soils, road dust, air and water, in schools, parks and other areas thus exposing people to e-waste related health problems (Heacock *et al.,* 2018)

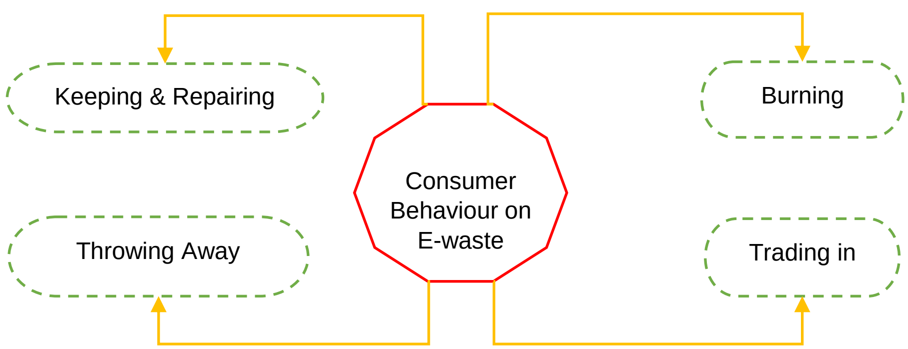
Formal e-waste involves proper equipment that allows safe extraction of the salvageable materials (Be this as it may varied safety standards means that some workers in such facilities maybe exposed to low-dose exposure). Surrounding communities are also exposed.

Adverse health effects to e-waste exposure include changes in lung function, thyroid function, hormone exposure, cytotoxicity and others (Nxele and Sly, 2014). E-waste recycling in developing countries is very poor and have not addressed environmental and health concerns sufficiently (Balasubramanian and Karthik, 2016).

### 2.27 CONSUMER BEHAVIOUR AND E-WASTE

The result of the increasingly rapid evolution of electronic technology coupled with rapid product obsolescence has compounded the e-waste problem (Otsuka *et al.,* 2012). The behaviour of consumers towards e-waste is of critical importance when it comes to its management. A multiplicity of problems in the management of e-waste are influenced by the behaviour of customers as this entails who does what with e-waste. Generally, some clients just keep e-waste with them for several reasons while others trade it in and get some financial benefits from their e-waste. Others just throw away the e-waste without any considerations of what will happen after it is thrown away. This is shown in Figure 2.21 below.

Figure 2.21: Consumer Behaviour on E-waste




Source: Survey, (2019).

Environmentally the throwing away culture is what has become the order of waste management within the cities of the developing countries. This is against the background that e-waste generated globally is growing at a rate nearly three times faster than the growth of the overall municipal solid waste (Schwep *et al.,* 2009). Be that as it may, developing countries are already strained with other forms of waste other than e-waste and according to Taru and Kuvarega, (2005) and Saungweme, (2012) the disposal of most forms of waste in the residential areas in Harare and others cities is illegal burning, burying, crude dumping in open spaces, rivers, drainage basins, as well as wetlands. This open and midnight dumping according to Manyanhaire, *et al.,* (2009) is illegal. The behaviour of customers is also triggered according to Chinobva and Makarati, (2011) by failure by local authorities to collect and manage waste, thus giving birth to waste dumping.

The ongoing economic crisis in Zimbabwe has affected e-waste management as the incapacitated waste management systems of cities like Harare cannot cope. According to Nhete, (2006), the antagonistic approach has resulted in the near-collapse of the country's waste management system.

## 2.28 SUSTAINABLE DEVELOPMENT GOALS (SDGs) AND E-WASTE MANAGEMENT

The goals for sustainable development for society are multifaceted and cover a lot of aspects regarding people's health, water cleanliness, habitable cities, climate change and other aspects. Goal number 11 is aimed at making the cities and human settlements safe and sustainable, this means that e-waste management should be properly done to ensure that there is limited heavy metals in the air, soil and water and thus protecting the people from the dangers that are caused by heavy metals. The idea of proper waste management then becomes an issue since most developing countries like Zimbabwe do not have proper landfills and a modern waste collection and separation, as well as treatment system. The fact that more than half of the world population resides in urban areas means more waste is being generated and therefore its management is important.

The birth of e-waste has and is causing the greatest challenge as heavy metals are now polluting urban waters, yet the governments cannot afford proper water treatment. This complicates goal number 6 that talks of availability and sustainable management of water and sanitation for all. This problem of water pollution is a threat to all people in the cities mostly in developing cities like Harare, because the roadside dumping and general mismanagement of waste results in water pollution and people end up drinking dirty water and thus defeating goal number 3 that aims to ensure a healthy life and promote well-being. This they argue is done by reducing death and illness from hazardous chemicals in water and soils. The problems of poor e-waste management cause pollution and serious health problems, mostly in the cities.

The improvement of water quality by reducing pollution, eliminating dumping and minimizing the release of hazardous chemicals and materials as well as protection and restoration of water-related ecosystems, wetlands, rivers and lakes is critical, but developing cities such as Harare are facing challenges in trying to manage their waste and as such heavy metals from e-waste and other forms of waste are killing people silently as the effects are least noticed and the environment polluted.

The sustainable development goals are aimed at ensuring that the society is habitable and free of pollution, but this is difficult to achieve, especially where there is no legislation to support these and also financial abilities by individual countries to ensure proper waste management.

The management of e-waste is very important if sustainable development is to be witnessed in developing countries. The management should follow a well-defined management system that takes note of the need to sort, recycle and recover critical substances and those that are not important and useless will be disposed of in the best manner possible and thus ensuring that there is little or no environmental pollution which is not only causing environmental and health problems but also climate change. Waste management in Zimbabwe needs urgent attention because there is mismanagement of household solid waste, e-waste included at all level from generation, storage, collection, transportation, right through to the disposal of waste (ILO, 2007).

Currently, as indicated in the model above there is no sorting of waste in Harare as dumping at Pomona is currently the city's way of doing waste management and worse so, e-waste is also dumped there along with the rest of the waste. Waste recycling is common at the dumpsite although these recyclers do not have the technology to process e-waste. According to Mandevere, (2016) waste is not separated at the point of generation, thus making it difficult to recycle and reuse. They also fail to collect waste due to the inadequacy of vehicles and fuel (Makwara, 2001).

Zimbabwe is using the crude dumping method of waste disposal where waste is just dumped and left uncovered as in the case of the Pomona dumpsite. Harare does not have a sanitary landfill that is lined to handle leaching and the waste is not compacted; and hazardous waste is dumped together with non-hazardous waste without separation or treatment (ILO, 2007). In Harare the Golden Quarry dumpsite produces leachate which flows along roads (ILO, 2007); this exposes people to diseases and contamination of underground water (Tevera, *et al.,* 2002; ZINWA, 2002).

The management of e-waste involves a multiplicity of aspects and hence an e-waste management policy must be put in place. The policy should be an all-inclusive policy that will ensure that e-waste is well managed.

Figure 2.22: E-waste Management Policy Contents


Source: Mallawarachchi. H, and Karunasena. G, (2012).

The policy should cover all the aspects indicated in Figure 2.22 above, as this is the ideal e-waste management policy. In most developed countries this is what is encompassed in their e-waste policies as they have most of the important issues such as resources, which enables them to monitor and control the e-waste management processes from birth to the cradle. This is, however, not the case with most developing countries whose resources are minimal, have no policy on e-waste and cannot ensure proper and full-fledged monitoring and management of e-waste. E-waste management in developing countries is still in its infancy due to most of these countries' lack of adequate capacity to handle e-waste. Consequently, e-waste continues to mount as cities are incapable of handling and managing it.

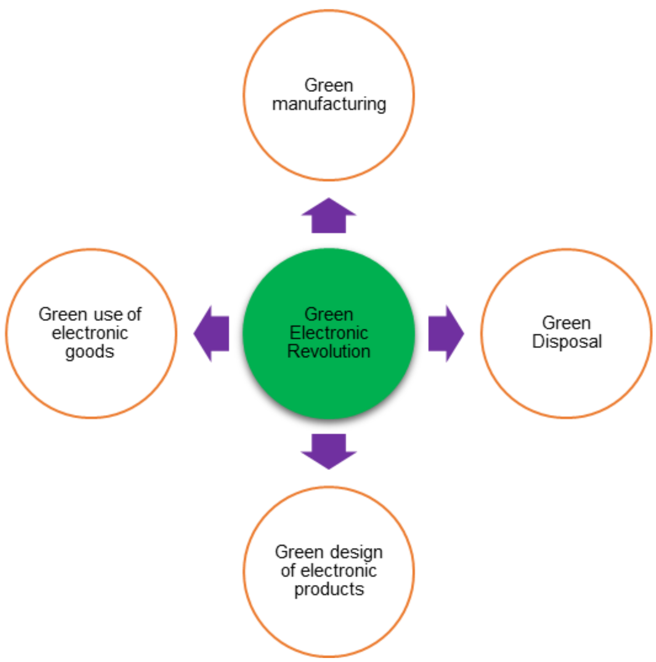
In Harare Zimbabwe, the EMA categorises e-waste under hazardous waste. This is contrary to Figure 2.21 above where the management of e-waste is seen to be complex as it involves more specialised machinery as well financial abilities. In light of this, given the amount of e-waste being generated globally, its management must be attended to seriously. The aspects of what an e-waste policy should carry should however be looked at from an international perspective as what a part of the world is working on may affect the other part. It is very important to note that according to Hossan *et al.,* (2015) technologically developed countries are the main source of e-products and e-waste generation and developing countries are in a vulnerable situation due to the lack of inventory data, waste management policies, and technology for sound environmental management.

## 2.29 ACTION TO HANDLE E-WASTE

Several initiatives have been taken to tackle global e-waste problems (Widmer *et al.,* 2008). These include among others the Basel Convention, Nairobi Declaration thus an agreement by the parties to the Basel Convention to accelerate the efforts to solve the global e-waste problems. The Step initiative, thus solving the e-waste problem, a UN-led initiative started at the "Electronics Goes Green"(EGG) Conference in Berlin to build an international platform to exchange and develop knowledge on WEEE systems among countries, The Silicon Valley Toxic Coalition (SVTC) and the computer take-back campaign engaged in research, advocacy and grassroots organizing to promote human health and environmental justice in response to the rapid growth of the high-tech industry.

The management of e-waste involves other various aspects to deal with green e-waste management and below in Figure 2.23 are some aspects of green management of e-waste. The aspects indicated on green e-waste shows that a lot should happen to ensure that there is minimal e-waste. The manufacturing of electrical and electronic goods calls for the use of products that do not carry a lot of dangerous substances, even the design of such products should also point to limited toxicity. The greening of e-waste, therefore, calls for e-waste management education to both the public as well as companies. This education will go a long way in ensuring an eco-friendly process from the production of resources to the final product.

Figure 2.23: Green E-Waste Management




Source: Adapted from, Yadav. R., (2015).

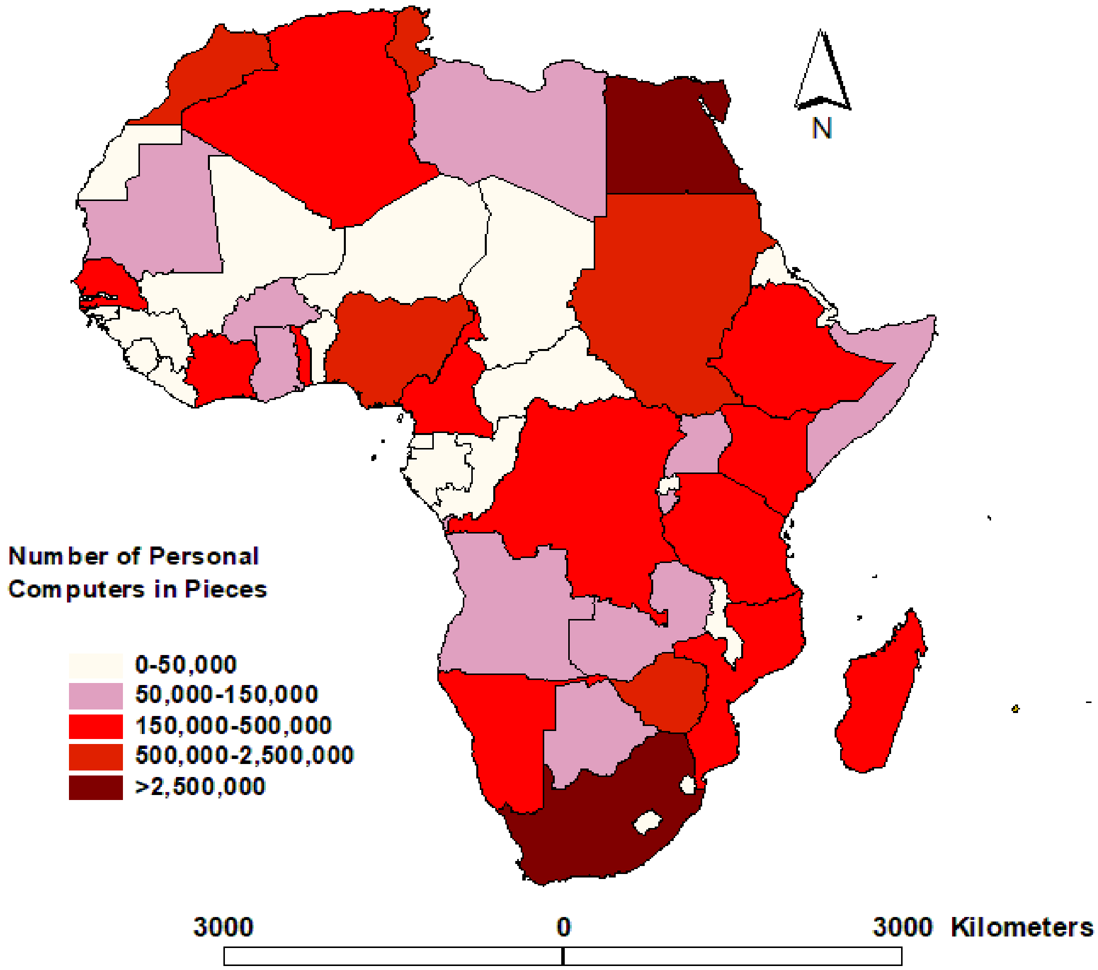
The rays of electronic waste are very critical and these are the green design of electronic products, which involves the production of environmentally friendly e-good with little or no dangerous substances such as heavy metals like mercury, which is being phased out in the production of fluorescent tubes. The life span of such goods should also belong so that their return to waste is limited and thus reducing e-waste. The use of the goods should as well be green thus, the use of electrical and electronic goods in a manner that will ensure that they last long with the owners keeping them long before discarding them into the waste stream.

Green manufacturing is also critical in that the producers of electrical and electronic goods should develop products that can last long, as well as stand the test of time with regards to the abilities and the general appearance. There is also the green disposal of e-waste at the end of their life cycle. This means that the obsolete electrical and electronic goods are either sent back to the producer to be properly recycled or in cases where this cannot happen, they should then be disposed of properly in a landfill designed for the disposal of e-waste. Such a process will ensure that no heavy metals go into the environment and threaten the lives and health of the people therein.

## 2.30 E-WASTE IN AFRICA

The digital gap and wound between Africa and the rest of the world have resulted in what the world has termed the digital divide which to date is causing e-waste problems as the developing world are dumping e-waste on Africa and Africa is receiving them knowingly or unknowingly to bridge the digital gap. Schulep, (2010) presented the number of computers in Africa as shown in Figure 2.24 below.

Figure 2.24: Distribution of personal computers in Africa




Source: Schluep, (2010).

Figure 2.24 above shows the number of computers in Africa by country and evidence shows that Zimbabwe falls in the second category. This means that there are a lot of computers in the range of 500 000 -2500 000 that are awaiting proper disposal. These are just personal computers only and discounts other products such as cell phones with Zimbabwe, currently estimated at 12,908,992 subscribers across all service providers. It is also important to note that while this is the case, other forms of electronic goods will also contribute to e-waste from all other sectors of the economy, including from households. For Zimbabwe, population concentration is more in Harare as it is the capital and the commercial hub of the country.

The general feeling is that the environment can deal with any form of waste deposited into it. Like so many other disposable parts of our life, most people give little or no thought and attention to what happens after our various and diverse commodities once they turn into e-waste. This is an indication that there is a lot that still has to be done in Zimbabwe regarding e-waste management. Since this starts with basic environmental education, the population should know the future of their electronic goods and their negative effects on both the current and future generations.

The idea of e-waste dumping has given birth to the concept of International Environmental Injustice (IEJ) and also the Ecological Modernisation (EM), which are topical aspects and prominent ideologies that underlie and pin the environmental talk the world over. These ideas are a result of the fact that the significant increase in e-waste has not been equally matched by the growth in processes related to collection, reuse and recycling of these electronic devices (Razmzy *et al.,* 2008). This is common in Africa where e-waste management is made complex by the fact that over 80% of the waste is not produced within African countries, but are imported in some cases as second-hand goods. The fact is that e-waste in Africa is fast exceeding the available management options and thus resulting in Africa as a dumping site for the world with regards to e-waste. It seems the end of life (EoL) of e-products that generate e-waste are causing e-waste challenges, as there are few if any available management mechanisms, especially in Harare, Zimbabwe.

Population growth worldwide is set to increase by 41% to 8.9 billion by 2050. This population growth is taking place in developing cities like Harare, Zimbabwe resulting in increased e-waste. Thousands of tonnes of e-waste are generated daily in Africa (Nhete, 2006). Most of this e-waste ends up in open dumpsites and wetlands, contaminating surface and underground water (ZINWA, 2002), posing a major health hazard (Conyers, 2001; Jerie, 2006). In West African cities, 70% of refuse collection trucks are always out of service (Achankeng, 2003) and this same situation applies to Harare, Zimbabwe and thus resulting in illegal dumping of e-waste. In 1999, the city of Harare failed to collect refuse from nearly all its residential areas because only seven of its trucks were operational out of the 47 trucks (USAID, 2009), this same situation is persisting and is even worse as the Zimbabwean economy keeps falling to the accumulation of e-waste and several other forms of waste.

The combination of high population resulting from the migration of people from the rural areas to Harare due to the hard economic environment, as they look for greener pastures, it also results in increased e-waste generation. This along with the poor collection of e-waste and shortages of specialised machinery to deal with e-waste has resulted in open space dumping giving room to the proliferation of associated diseases (Chirisa, 2012).

### 2.31 E-WASTE MANAGEMENT IN AFRICAN COUNTRIES

The United Nations Statistics Division (UNSD, 2011) defined solid waste as all material that is not prime products and has no further use in terms of their purpose of production, transformation or consumption. Miller (2004), however, argues that not all waste should be discarded as some can be transformed into useful products through recycling. This is true with regards to electronic waste as there is talk on urban mining. E-waste from various economic activities needs to be managed properly to ensure that e-waste related environmental problems are minimized.

Practical Action Southern Africa (PASA, 2006) indicated that more than 2.5 million tonnes of household and industrial waste are produced per annum in urban areas across Zimbabwe and this includes e-waste in Harare. Further to this, the urban waste collection was reported in 2006 to have dropped from at least 80% (in the mid-1990s) of total waste generated to as low as 30% in some large and small towns, (Tevera, 1991). This is true in Harare as a multiplicity of roadside dumps are evident. According to the United Nations Environmental Programme (UNEP, 2008,) half the urban population in developing countries do not have adequate solid waste disposal and as result several waste-related problems are common and these include e-waste heavy metal related problems.

Achankeng (2003) revealed that municipal household solid waste management constitutes one of the most serious service provision challenges facing African towns and cities like Harare. This is further complicated due to the coming in a new form of waste in which is e-waste. As such due to the complexity of e-waste management, Zurbrugg (2003) indicated that collaboration by a large number of stakeholders is essential for the success of an effective e-waste management system.

Medina (2010) indicated that many cities in the developing world such as Harare collect less than half of the waste generated and dump it in open spaces. This means that most of the e-waste is being generated in Harare is mismanaged and consequently dumped in open spaces. Sharing the same sentiments was Senkoro (2003) who asserted that there is overwhelming evidence in the form of growing piles of uncollected solid waste that municipalities in Sub-Saharan Africa are failing to keep pace with the scale of urbanization, and the environmental and health problems associated with it and the crisis is worsened by the coming in of the electronic revolution which has resulted in the generation of e-waste whose heavy metals cause serious health problems and environmental pollution.

Zimbabwe is using the crude dumping method of e-waste disposal, thus to say e-waste is just dumped all over across the city on illegal dumpsites and in cases where it is dumped at Pomona or Golden Quarry dumpsites, some scavengers pick it up for recycling, reuse or breaking to recover some critical components that they will then resell.

Harare does not have a proper sanitary landfill that is lined and can reduce or hinder the leaching and infiltration of heavy metals from e-waste. This results in the pollution of the soils and underground water. It has the potential of polluting sources of water for the city of Harare, such as urban boreholes, rivers such as the Mukuvisi, as well as the main water source which is Lake Chivero, because hazardous waste is dumped along with non-hazardous waste without separation or treatment, yet this treatment is the foundation to proper e-waste management (ILO, 2007).

Solid waste management is defined as the range of activities in the handling of waste, including generation, storage, collection, transportation, processing, treatment and disposal (Mandevere 2016). This is supported by Chiwandamira, (2000) who indicated that the goal of waste management is to ensure that the disposal of waste does not result in environmental pollution and degradation. The problem of indiscriminate dumping of waste has become ubiquitous in Harare, Zimbabwe (Chirisa, 2012). This means with e-waste added the levels of pollution are also increased worse in Harare, where there are no proper management facilities for both hazardous and non-hazardous waste.

The Golden Quarry dumpsite produces leachate which flows along roads and this carries with it heavy metal from e-waste and other sources of heavy metals. This exposes people to diseases that are heavy metal related such as cancer and contamination of surface as well as underground water (ZINWA, 2002).

Harare being the capital city of Zimbabwe, economic activities are rife and this attracts from the rural areas and other small towns. In turn, the increase in population contributes to the generation of e-waste. Since everyone owns an electric gadget that will be e-waste at one stage or the other in their life cycle, they must know about e-waste and its disposal.

Basically, in Harare waste disposal include illegal burning, burying, crude dumping in open spaces, rivers and drainage basins as well as composting (Saungweme, 2012). This is due to poor solid waste collection systems. According to Environment Africa (2013), there is a cadaster of twenty eight (28) recycling companies in Zimbabwe. However, of these, none is directly into e-waste recycling except one or two recycling batteries along with other forms of waste. The management of e-waste in Harare, therefore, become very problematic for this reason.

## 2.32 THEORETICAL UNDERPINNINGS OF THE STUDY

A theoretical framework anchors the study in an existing body of knowledge (Lysaght, 2011). Theories in this study were the lens that facilitated this researcher's understanding of the processes, issues and forces at play in e-waste management. The theoretical underpinnings of the study were to do with various issues surrounding e-waste management. However, while they were derived from multiple theories such as the Theory of waste management, the environmental justice theory, Theory of Environmentally Responsible Behaviour, The Environmental Citizenship Theory, The

Value-Belief-Norm Theory of Environmentalism, Theory of Planned Behavior (TPB), Expectancy Theory (ET), Stakeholder' Theory (ST), and Diffusion of Innovation Model, they were primarily anchored on waste management issues. These theories helped in the interpretation and understanding of the phenomenon under study to impute and ascribe meaning to reality. Each of these theories has an explanatory validity in the study, the majority of the theories cited above fitted well and were able to give illuminating explanations on the phenomena under investigation. These theories could thus, be regarded as having clear explanatory validity to the study at hand. They apply clearly to the study. After a critical analysis of all the theories above each one of them had a critical function in explaining e-waste management as well as human issues surrounding environmental and e-waste management. The following is a critical evaluation of the extent to which each of the theories referred to above is of explanatory significance to this study.

### 2.32.1 THE ENVIRONMENTAL JUSTICE THEORY

Basically, the theory focuses on communities. The theory states that the political clout of a racial group, a country or an individual determines to a greater extent the flow of burdens versus benefits. The theory focuses on the proportionate sharing of environmental benefits and burdens between different categories of persons. It is based upon the recognition that environmental costs and benefits are not distributed in a fair and equitable manner and that traditional environmentalism has not been sufficiently concerned with very divergent local situations and the plight of minorities. Thus, it can be said that the focus of attention of the theory is to shift attention from the environment to people specifically communities. It seeks to show that environmental protection should not be planned in a vacuum and that environmental goals should consider social, political and economic realities. In a broad sense, the theory posits that environmental justice is about positive discrimination: it seeks to achieve a redistribution of the costs of environmental justice so as to lower the disproportionately high burden borne by some segments of society just like in the case of e-waste where effects are felt more in the developing than the developed countries.

Essentially the theory was used to understand the international, regional and local drive to deal with e-waste. The theory was used to understand the inter-connectedness in e-waste management efforts. The theory focuses on environmental waste as a social problem affecting everybody in the society and makes it everybody's duty to bear the costs of management. Thus, principally the theory was useful in understanding planning and efforts exerted in e-waste management. It helped in evaluating approaches being used in e-waste management. The essence of the theory lies in its disillusionment with mainstream environmentalism which normally advocated for the command-and-control approach. Kamreri-Mbote and Cullett, (2017) queries the effectiveness of the fortress approach in environmental waste management by stating that uniform laws in traditional environmentalism do not affect everyone uniformly. Thus, the essence of the theory to the study lies in its ability to draw the necessary link between conservation and economically disadvantaged communities which Kameri-Mbote and Cullett (2017) posits have been missing in environmental laws. Thus, the theory can also be used to understand the relationship between developed and developing countries in terms of e-waste management. Evidence from the study posits that developing countries Zimbabwe being a case in point have been used as dumping grounds for cheap technology by countries such as China which has accelerated e-waste management problems in the resource constrained country.

### 2.32.2 INSTITUTIONAL THEORY

The Theory as postulated states that individual behaviour in organisations is governed by values, cognitive frames, rules and routines. Further, Greenwood *et al.,* (2011) postulates that as institutional pressures characterize each sector depending on its regulatory, political and social components, adaptation to institutional pressures leads to institutional "isomorphism" within a given sector. Principally the theory was used to understand how institutional and management frameworks in e-waste management works. The theory was used to understand how the pressures exerted by economic, political or social constituents affect the adoption of different environmental management tools. The theory has been tested in empirical studies conducted in Asian, South American, African and post-Soviet countries Baek, 2017; Fikru, 2016; Montiel et al., 2012; Rowe & Guthrie, 2010; Salmi, 2008). Evidence from these studies show that the theory can be used to understand the uptake of different environmental management tools/approaches. Institutional theory can help provide an explanation for institutional decisions and activities as it considers the processes by which structures, including schemes, rules, norms, and routines, become established as authoritative guidelines for social behaviour.

### 2.32.3 SOCIAL EXCHANGE THEORY (PETER BLAU, 1964)

The Social Exchange Theory views social interaction as partly based on what someone may 'gain or lose' by being with others. The theory regards social interaction as interactions of utility-maximizing individuals. Individuals think about their relationships in economic terms. Interpersonal behaviour is all about resource seeking. Thus the Social Exchange Theory states that social interactions are tied to the self-interest of both parties interacting (McGehee & Andereck, 2004; West & Turner, 2010). This is just the case with the relationship between the developed and developing countries concerning the electronic revolution where the relationship in terms of electrical and electronic goods trade seems mutual yet it is mutually exclusive. People view life as a market place where rewards are sought for certain costs (West & Turner, 2000,2010). Social actors interact to obtain desired goals whilst sacrificing resources such as time and energy. Thus, this theory enables us to understand relationship formations, maintenance and dissolutions between the West and Africa in terms of trade in electronic gadgets.

This theory can be used to understand the actors in this marriage for convenience. The social actors are said to be rational beings (Smith & Hamon, 2012). Thus, when actors on the front stage prolong their social interaction, we can understand that the continuation of the relationship means the parties are benefitting. This sustained relationship between the social actors is further given credence by the increased number of social actors who continue to import e-products from the West and Eastern countries like China. The long-term impacts such as environmental pollution of such electrical products are ignored in such relationships by the available international conventions handling such.

### 2.32.4 THE STAKEHOLDER THEORY (FREEMAN, 1984)

Every organization has a moral responsibility towards all stakeholders (Freeman, 1984; Freeman, Velamuri and Moriarty, 2006). People who own stock in a business are not the only ones who stand to gain or lose when a business makes decisions. The underlying assumption in this theory is that organizations as well as individuals possess moral status and therefore should act in a morally responsible manner. It relates to the moral principles or conscience (Friedman and Miles, 2006). The theory helps in the responsibility of e-waste management. Thus, principally this theory will help in illuminating the role of responsible authorities in the success or failures of e-waste management initiatives in Harare, Zimbabwe.

### 2.32.5 THE EXPECTANCY THEORY (VICTOR, H. VROOM, 1964)

The Expectancy Theory by Vroom (1964) states that behavioural motivation is based on desired goal (expectancy) or reward (instrumentality) or if the effort is worth it (valence). Motivation to behave in a certain way is based on the expectation that the effort will result in the desired goal (Vroom, 1964). This theory was used to illustrate the motives of stakeholders and individuals in participating in e-waste management. This theory is a micro-level theory that affords us a lens to understanding what motivates stakeholders and individuals to behave in the way they do regarding e-waste management in this particular case.

Expectancy theory is an essential theory that underlines the concept of performance management (Buch, 2015). Vroom (1964) expectancy theory assumes that behaviour results from conscious choices among alternatives whose purpose is to maximise pleasure and to minimise pain. Vroom (1964) realised that stakeholders' behaviour is based on individual factors such as personality, skills, knowledge, experiences and abilities, where effort and performance are linked in a person's motivation. Thus, the theory was used to understand the behaviour of stakeholders and individuals towards e-waste management in Harare, Zimbabwe.

### 2.32.6 GOAL SETTING THEORY OF MANAGEMENT PERFORMANCE SYSTEM

Goal setting refers to goals being set for the future for subsequent performance of an individual or organisations (Robbins & Judge (2013). The theory emphasizes the important relationship between goals and performance (Locke & Latham, 1990). Locke and Latham (1990) postulate that when individuals or organisations set more difficult goals, then they perform better since behaviour is a result of conscious goals and intentions, by setting goals an environmental manager should be in a position to influence the behaviour of members of the public. Thus, this theory was used to understand the performance of governmental and other organisations in e-waste management vis-a-vis existing e-waste local, regional and environmental laws.

### 2.32.7 THE HEALTH BELIEF MODEL (IRWIN ROSEN STOCK, 1966)

Personal beliefs influence health behaviour. Health behaviour is determined by personal beliefs or perceptions about a disease and the strategies available to decrease the occurrence (Hochbaum, 1958). Personal perception is influenced by the whole range of intra-personal factors affecting health behaviour. The theory has four main constructs perceived seriousness, perceived susceptibility, perceived benefits, perceived barriers and cues to action.

**Perceived Seriousness**

The perception of how severe a disease can get is based on clinical knowledge or personal beliefs as shaped by society (McCormick-Brown, 1999). This construct will be used to understand how stakeholders in e-waste management understand the environmental and health threats posed by e-waste mismanagement. This perception of the seriousness of the threat forces them to either practice e-waste management or continue with untamed e-waste polluting behaviour.

**Perceived Susceptibility**

Susceptibility perceptions lead people to adopt healthier behaviour. Belcher, Sternberg, Wolotski, Halkitis, and Hoff (2005) assert that if the perceived risk is high, people are likely to engage in behaviours that decrease the perceived risk. The scholars give an example of the use of condoms to decrease the susceptibility of contracting HIV infection. When susceptibility is combined with seriousness in the perceived susceptibility, it becomes a threat that leads to behaviour change (Stretcher & Rosenstock, 1997). This concept allows us to understand how stakeholders are motivated to undertake e-waste management. Secondly, how they change their feelings towards e-waste management; especially when they come to understand the dangers surrounding heavy metals in e-waste.

**Perceived Benefits**

However, people only change their behaviour if they can see the value in it. People adopt a new behaviour if they can benefit from the new behaviour. This construct will be used to understand the motive or drive behind e-waste management by stakeholders. In this regard, if companies and individuals can benefit from e-waste recycling and urban mining, then there is a need for proper electrical and electronic products monitoring and eventual disposal.

**Perceived Barriers**

This concept is an individual's evaluation of barriers to the adoption of new behaviour. The Prevention, (2004) asserts that for a new behaviour to be adopted the perceived benefits of the new behaviour must outweigh the cost of continuing with old habits. Thus, for a stakeholder to adopt the new behaviour and overcome barriers, it means that they value the outcome from e-waste management. What value stakeholders perceive in e-waste management provides or fuels their desire to undertake e-waste management. This is critical as the current situation in Harare, Zimbabwe shows reluctance on e-waste management by both authorities and individuals for perceived lack of technology and resources.

**Cues to Action**

Graham (2002), posits that cues to action are events, people or things that are influential in leading to the adoption of a new behaviour change. This cue helped us understand what influences e-waste management behaviour in Harare, Zimbabwe.

### 2.32.8 ADMINISTRATIVE MANAGEMENT THEORY

Administrative management theory attempts to find a rational way to design an organisation as a whole. The theory calls for a formalised administrative structure, a clear division of labour and delegation of power and authority to administrators relevant to their areas of responsibilities (Vincent, 2014). Fayol (2001) states that division of work or specialisation increases productivity in technical and managerial work. Thus, this theory was used to illustrate the effective ways of designing/crafting effective frameworks of e-waste management.

### 2.32.9 BEHAVIORAL CHANGE MODEL

This reasoning was directly associated with the supposition that if people were better informed, they would become more aware of environmental problems and consequently, would be motivated to behave in an environmentally responsible manner. The behavioural model, though very simplistic, provides a base for the consideration of possible relationship existing between environmental knowledge, environmental awareness and attitude and how these can translate to action or inaction. Good knowledge of environmental variables may not necessarily imply good and sustainable environmental behaviour. On the other hand, lack of environmental knowledge or awareness may also not necessarily imply a poor environmental practice. Therefore, this theory was used to illustrate the relationship between awareness and change in behaviour towards environmental consciousness and ultimately e-waste management.

### 2.32.10 THEORY OF ENVIRONMENTALLY RESPONSIBLE BEHAVIOR (ERB)

The ERB theory was proposed by Hines, Hungerford and Tomera. The model argues that possessing an intention of acting is a major factor influencing ERB. The model of Environmentally Responsible Behaviour indicates that the following variables; intention to act, locus of control (an internalized sense of personal control over the events in one's own life), attitudes, sense of personal responsibility, and knowledge suggested whether a person would adopt a behaviour or not. This theory was used to understand that, the internal control centre has a very considerable impact on the intention of acting, which determines an individual's ERB substantially. This model also highlights the existence of a relationship between the control centre, attitudes of individuals and their intention to act. For instance, people dispose of their waste to include e-waste materials in the middle of the streets and open areas in cities like Harare despite regulations from waste management authorities, prohibiting these acts. Many of these flouters do so at odd hours when law enforcement agencies are not available. Others are influenced to indiscriminately dump these waste materials because they see others doing so, yet some still find ways of decently disposing of their waste materials. Knowledge alone is grossly insufficient to act responsibly towards the environment. While some individuals' knowledge of the environment and its regulations could prompt them to have a good attitude which would translate to good intentions to act, other individuals may go through internal and external control, such as being influenced by the actions of others or holding strongly to a belief to act rightly despite the actions of others towards the environment. This is a critical theory in e-waste management.

### 2.32.11 REASONED/RESPONSIBLE ACTION THEORY

This theory was proposed by Ajzen and Fishbein (1980). The Reasoned Action Theory assumes that human behaviour is grounded in rational thought. The model uses the Principle of Compatibility that predicts that attitudes reflect behaviour only to the extent that the two refer to the same valued outcome state of being (evaluative disposition). The theory stipulates that the intention of acting has a direct effect on behaviour and that it can be predicted by attitudes. These attitudes are shaped by subjective norms and beliefs, and situational factors influence these variables' relative importance. Reasoned Action Theory accounts for times when people have good intentions, but translating those intentions into behaviour is thwarted due to a lack of confidence or the feeling of lack of control over the behaviour.

This interaction contributes to developing environmentally favourable attitudes towards relevant issues that in turn lead to reinforcing the intention to act responsibly. The theory of Reasoned Action is important to the extent that it provides a foundation for the understanding of why people may not act in favour of the environment, despite having good intentions either due to their lack of confidence or for reasons that they feel they lack control above the behaviour. Furthermore, as asserted by Azjen and Fishbein, (1977) based on different experiences and different normative beliefs, people may form different beliefs on the consequences of performing a behaviour. These beliefs, in turn, determine attitudes and subjective norms which then determine the intention and the corresponding behaviour. A better understanding of a behaviour can be gained by tracing its determinants back to underlying beliefs. The model gives further explanations as to how good intentions for the environment are not enough in themselves to propel action.

### 2.32.12 THEORY OF PLANNED BEHAVIOR

The Planned Behaviour Theory, this model of planned environmental behaviour considers the intention to act and objective situational factor as direct determinants of pro-environmental behaviour. The intention itself is considered summarizing the interplay of cognitive variables which include; (knowledge of action strategies and issues, action skills) as well as personality variables (locus of control, attitudes and personal responsibility). The Planned Behaviour Theory grew out of the Theory of Reasoned Action and it suggests that human behaviour is influenced by three belief constructs: beliefs about consequences; expectations of others, and, things that may support or prevent the behaviour.

A strong premise of the theory is that, at the conceptual level, links among influences of behaviour and their effects are captured through one of the components of the model or relationships in the model. The application of this model to this study is that the model provides further explanations into the connection between knowledge, attitude, behavioural intention and actual behaviour as they influence e-waste management practices. Knowledge is not a specific component in the model but "attitudes are a function of beliefs"; since in this context, beliefs refer to knowledge about a specific behaviour. Azjen's model further allows for the representation of cognitive elements through effective elements by their influence on beliefs. For instance, when a person understands that he/she has control over a certain situation, his or her behavioural intentions reflect this understanding as much as his/her beliefs determine the outcome of certain behaviour.

### 2.32.13 THE ENVIRONMENTAL CITIZENSHIP MODEL

This model was proposed by Hungerford and Volk. The Hungerford Volk Model arrays three stages of educational involvement ranging from first exposure (entry) to real involvement (empowerment). It suggests that each stage has certain knowledge and attitude characteristics. In the Environmental Citizenship Model, Hungerford and

Tomera grouped the variables that influence whether a person acts into three categories. These are Entry-level variables such as general sensitivity to and knowledge of the environment. Ownership variables include in-depth knowledge, personal commitment, resolve and Empowerment variables such as acting skills, the focus of control, and intention to act.

This theory is vitally important because of its potential to evolve a citizenry that is touched by the feelings of the environment. It considers, who will bear its burdens to the extent of possessing skills that can enable them to act in the interest of the environment. One popular environmental variable for instance is that of solid waste. This theory could become applicable such that whether it be the purchase of goods or undertaking of services; the one thing that will be paramount in the minds of the citizens is the sustainability of the environment. Similarly, when it comes to the generation, disposal and management of e-wastes; citizens will be most concerned with a sustainable manner of e-waste generation and management hinged on avoidance, reduction, re-use and recycling.

In application, the Hungerford Volk Model identifies numerous variables required to be an environmentally literate citizen. Secondly, the model provides a basis for the classification and separation of environmental literacy variables according to their importance either as a major variable or a minor variable. Also, the model provides a framework/scale to identify the level of an individual in the literacy ladder, such that one can tell if a citizen is in the entry-level, ownership level, empowerment level or has grown to become an environmentally responsible citizen.

### 2.32.14 THE VALUE-BELIEF-NORM THEORY OF ENVIRONMENTALISM

The Value Belief Norm (VBN) Theory was proposed by Paul Stern in 1999. The value-belief-norm (VBN) theory of environmentalism has its roots in some of the above theoretical accounts linking value theory, norm-activation theory, and the New Environmental Paradigm (NEP) perspective through a causal chain of five variables leading to behaviour: personal values (especially altruistic values). This chain of five variables, grouped into categories of values, beliefs, and norms; influences whether a person is likely to adopt some environmental behaviours. VBN theory measures from other theories to account for three types of non-activist environmentalism: these include environmental citizenship, private-sphere behaviour and policy support (willingness to sacrifice). The discovery was that the VBN cluster of variables was far stronger in predicting each behavioural indicator than the other theories, even when other theories were taken in combination.

On the VBN, behaviour that will be environmentally significant is dauntingly complex, both in its variety and in the causal influences on it. Stern affirmed that, while a general theory is still yet to be arrived at, enough is known to present a framework that can increase theoretical coherence. This framework will include typologies of environmentally significant behaviours and their causes as well as a growing set of empirical propositions about these variables. The Value Belief Norm theory, among the hitherto discussed theories, provides a more elucidative explanation of the human-environment interaction and how these interactions can affect each other, taking into consideration a relatively ample number of variables responsible for cause and action. Furthermore, the theory applies to this study because The Value Belief Norm approach offers a good account for the causes of the general predisposition toward pro-environmental behaviour. Environmental practices depend on a broad range of causal factors, both general and behaviour-specific. A general theory of environmentalism may therefore not be very useful for changing specific behaviours. Different types of environmental practices have different causes. These causal factors may vary greatly across behaviours and individuals; hence, each target behaviour should be theorized separately. In addition to the models and theories discussed above, two theories have been identified that affect environmental behaviour.

### 2.32.15 DIFFUSION OF INNOVATION MODEL (EVERETT ROGERS 1962)

In 1962, Everett Rogers introduced the concept of innovation diffusion. The theory purports that change spreads in a population through a normal distribution of willingness to accept new ideas. At the level of the individual, behavioural adoption occurs through the stages of knowledge, persuasion, decision, implementation and confirmation. Several studies have considered and applied diffusion theory. According to diffusion theory, behaviours are affected across a community through change agents. Four elements would affect a change agent's behaviour while diffusing innovation. These are involvement; social support; response information and; intrinsic control. This model is important because of its ability to identify and assess the environmental literacy inducing information possessed by individuals, concerning the content, sources, quality and effect; within a social context, social process and social support as upheld by this model.

### 2.32.16 CAPABILITIES THEORY (CHANDLER, 1997)

The theory focuses on the capabilities of organizations ability to do certain kinds of things well enough to make it competitively viable in delivering related goods and services (Chandler, 1977). Further, the scholar posits that within this tradition, choice of technique is not a matter of selection from a menu of possibilities with known characteristics, rather it is a combination of inheritance from past practices and ongoing learning about the possibilities of the present and future. This theory was used as a middle level theory to understand how local authorities determine e-waste management approaches to use. The theory would be used to understand the determinants in e-waste management approach being used. The theory states that while capacities may equip organizations for effective performance along certain competitive dimensions, other kinds of activities may fall outside their normal scopes of awareness, inquiry, or expertise. Thus, this theory was also used to understand the capacities of cities and town councils in managing e-waste. Thus, the theory generally was used to understand the reasons behind the state of affairs in the management of e-waste in Harare, Zimbabwe. Further, the theory states that organizations often stay with their waste management practices, not because alternatives are not available, or are costlier, but because they are conditioned to do so. Thus, the theory was also used to synthesize the respondent disposition towards certain e-waste management approaches, as well as organizational dispositions towards adoption of alternative and effective e-waste management approaches.

## 2.33 CHAPTER SUMMARY

The amount of e-waste generated in Harare is proportional to its population and the mean living standard of the people in the city. This means that the bigger the population the more e-waste generated. Recent studies established the underlying problem of e-waste management in most cities of the developing world, Harare included. However, the focus of most of these studies was on e-waste management and health problems of e-waste and very few on developing a model for effective e-waste management. While e-waste management practices have been investigated in studies globally, continentally and nationally, little has been published regarding the effectiveness of available e-waste management strategies. The role of the current environmental legislation on e-waste management, education to the general populace on the dangers of e-waste related heavy metals, statistics regarding e-waste in Harare, the role of the law in the importation of e-good into Zimbabwe remain researchable areas. This study focused on assessing the existing structures on e-waste management and crafting the vital considerations for the development of an effective model for e-waste management. The theories that have been adopted in this study have been chosen in such a way to complement each other and mitigate the weakness of the other. Other micro-level theories were engaged to explain the various sub-themes in the document which included customer behaviour on e-waste issues. The next section focuses on the methodology which was employed in this research on assessing e-waste management in Harare, Zimbabwe.

# Chapter 3

## RESEARCH METHODOLOGY

### 3.1 INTRODUCTION

This chapter focuses on the research methodology adopted to address the following research objectives: What electronic waste management approaches are being used in Harare? What are the existing environmental laws on electronic waste management in Zimbabwe? How effective are the electronic waste management strategies being used in Harare? What is the level of the population of Harare's understanding of the phenomenon of e-waste management? And, What model can be developed for effective e-waste management in Harare? Specifically, the chapter unpacks the methodological and philosophical approaches followed, sampling techniques, data collection techniques, data organisation, ethical considerations, and validity and reliability adopted by the study. Chapter three also presents a framework for data analysis and projects a data analysis strategy for meaningful results. A summary is provided at the end of the chapter.

### 3.2 STUDY AREA

This study sought to assess electronic waste management in Harare. Harare is the capital city of Zimbabwe, a landlocked Southern African country that shares its borders with Botswana to the west, South Africa to the south, and Mozambique to the east, and Zambia to the north (see Figure 3.1 insert). Zimbabwe lies between longitudes 25 and 33 degrees East and Latitude 15 and 23 degrees south. It is situated at an altitude of 1,483 meters and has a warm temperate climate. Its climatic year is divided into three main seasons and these are the warm-wet season (November – April), the cool-dry season (May-August) and the hot-dry season (September - October). Temperatures range from 2-22 degrees Celsius in July (the coldest month) to 15 - 29 degrees Celsius in October (the hottest month).

Zimbabwe is administratively divided into provinces, districts, cities, towns, wards, growth points and villages. Of these, Harare is the leading industrial, commercial, financial and communication centre of the country's cities (see Figure 3.1). It has an estimated geographical area of 961 square kilometres (k$m^2$) making it both a province and city with 46 wards. The boundaries of the city are shown in the map in Figure 3.2 below. Harare is administered from various places. These are the: Town House, Rowan-Martin Building, Cleveland Building, Graniteside Waste Management section and several other places situated in various localities within various residential areas.

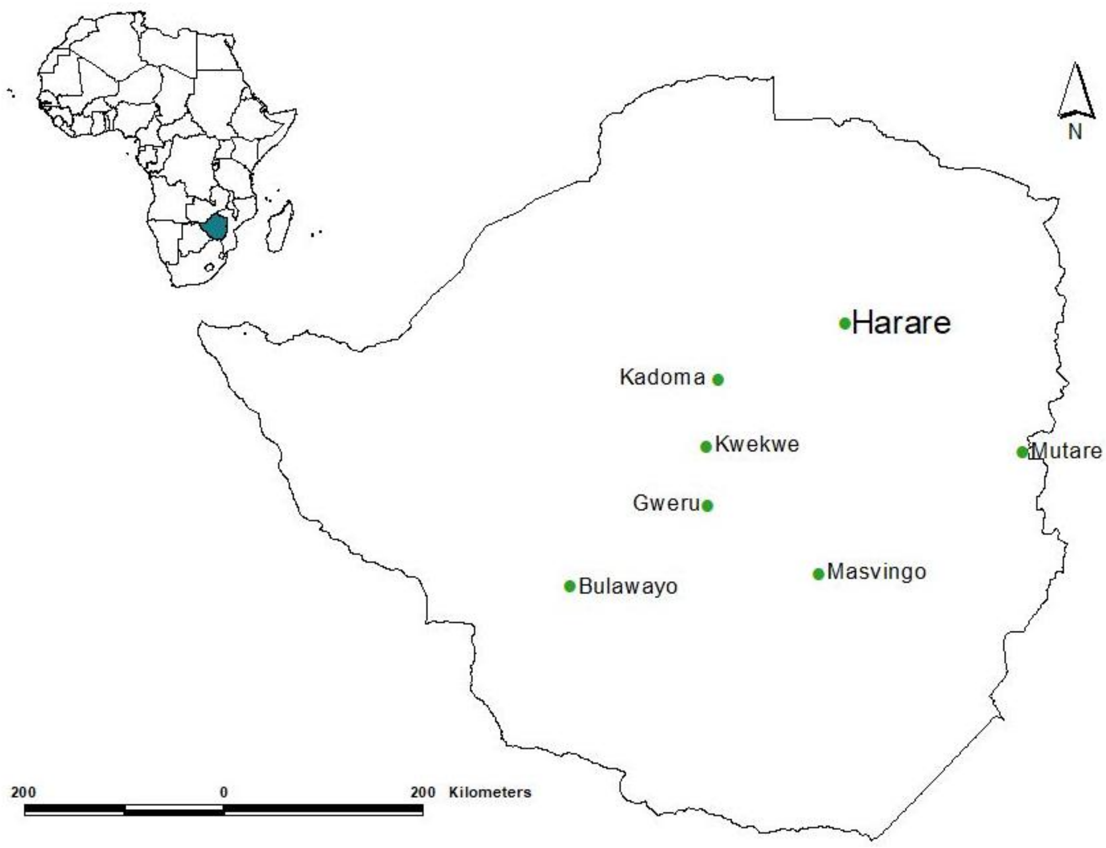
Waste management is undertaken in most of Zimbabwe's cities, towns and growth points. The population of an area is crucial to the generation and management of waste. This is since its total population, the number of households and economic activities determine the electronic gadgets owned and ultimately, the possible e-waste that will require disposal management. The city of Harare is a multi-racial society with over 10 races residing in various locations of the city. In 2020, the city's population was estimated at 4 141 849. In addition to this, Harare is surrounded by other cities and town such as Chitungwiza, Norton, Mazowe, Epworth and Ruwa that act as satellites and dormitories to it. These add to Harare's population and waste during the day. Generally, Harare's waste management is the responsibility of the City's waste management department. Roadside dumpsites are common, especially in the high and medium density suburbs of Mbare, Highfield, Mufakose, Budiriro, Mabvuku, Masasa and others. However, this is not so in the low-density suburbs.

At one point, Harare was known as "The Sunshine City" because of its cleanliness. However, in recent years, the city has struggled to manage its waste and maintain its "sunshine city" status. Harare's main dumpsite is Pomona, which is located to the north of the City Centre. Originally, the city had two dumpsites. These were Pomona in the Pomona area and The Golden Quarry in Westlea, west of Harare, Currently, however, the Golden Quarry dumpsite is unavailable for the indiscriminate disposal of waste, only hazardous substances can be dumped there. This is because the site used to be a quarry mine and is believed to have an underlying impermeable rock that prevents the possibility of hazardous substances polluting the environment. Both Pomona and

Golden Quarry dumpsites have active informal waste recyclers who collect waste material with the potential for reuse.

Some of the same informal waste recyclers also frequent and work various illegal dumpsites dotted around the City. These include those in most high-density suburbs of Harare such as Mbare, Highfields and others. The informal e-waste recyclers frequently visit such dumpsites to pick what they perceive are products that can be resold or dismantled to sell critical parts. In so doing, they help reduce the e-waste menace that the responsible authorities fail to control and manage.

Figure 3.1: Map showing the study area in Zimbabwe




Source: Primary Data, (2019).

Figure 3.2: Detailed map of Harare the study area


Source: Primary Data, (2019).

Table 3.1 below shows the total population in the City's households as well as the average household size in 2015. Given that on average each household owns at least one television set, digital satellite television (DSTV) decoder, a refrigerator, cell phone, desktop computer and possibly a laptop and hi-fi, the table gives a rough indication of the potential e-waste the City of Harare is likely to produce when the gadgets likely become e-waste.

Table 3-1: Population and Number of Households in Harare

| WARDS | MALE | FEMALE | TOTALS | HOUSEHOLDS | AVERAGE SIZE |
|---|---|---|---|---|---|
| 46 | 1,330,721 | 2,811,128 | 4,141,849 | 371,570 | 4,0 |

*Source: Zimstat, (2016).*

### 3.3 RESEARCH DESIGN

A research design as cited by Gray (2013) is a well-laid down plan that elaborates how, when and where research data has to be attained and analysed. It focuses on the logical steps that are undertaken to achieve an outcome in research. It is the logic that links the data to be collected and the conclusion to be drawn to the initial questions and in the process ensures coherence (Gray, 2013; Roller & Lavrakas, 2015). There are three main types of research designs which are namely, explanatory or casual, exploratory and descriptive (Bryman, 2015).

The research design adopted in this research study was a combination of exploration, experimental and descriptive research designs, also known as mixed methodology. An exploratory research design is most suitable when either the study topic is new or when there is a dearth of relevant literature as the design puts major emphasis on the discovery of new insights and ideas (Neuman & Robson, 2009; Robson, 2007; Saunders & Lewis, 2009). This kind of research design involves an explanation of scenarios and the involved variable. This then leads to a description of the subject matter and this is done through literature review and interviewing experts in the research area. The major focus of the research study remains descriptive.

The mixed methodology represents both quantitative and qualitative research. It is one in which the researcher tends to base knowledge claims on pragmatic grounds (e.g. consequence-oriented, problem-centered and pluralistic) (Lincoln & Guba, 2000). The approach employs strategies of inquiry that involve collecting data either simultaneously or sequentially to best understand research problems. Bryman (2014) point out that mixed-method research provides more evidence for studying a research problem than either qualitative or quantitative research alone. The data collection also involved gathering both numeric information as well as text information, so that the final database represents both quantitative and qualitative information.

For the experimental research design, water and soil samples were collected from designated areas in Harare and taken to the laboratory (EMAL) for testing the levels of heavy metals in both the soil and water around the city of Harare. Descriptive analysis was then used to discuss the findings from the laboratory. According to Charles, (1988) "descriptive research describes conditions, situations and events of the present". This aspect was covered in describing the nature and distribution of e-waste in Harare, Zimbabwe.

This study also adopted the cross-sectional survey research design. Bryman (2014) state that surveys are a specific type of field study that involves the collection of data from a sample of elements drawn from a well-defined population. Bryman (2014) asserts that cross-sectional studies or surveys measure both the exposure and outcome in a sample of the population at a point in time. Ideally, the sample should be randomly selected from the population. Bryman (2014) noted that a cross-sectional survey collects data to make inferences about a population of interest (universe) at one point in time.

This type of design goes hand in glove with the demands of the study that was at hand which wanted to critically review the management of e-waste in Harare the capital city of Zimbabwe. The survey involved a wide distribution of questionnaires or interviews designed to get certain data from the people. According to Marx (1998) this is intended to provide answers to questions such as 'who,' 'what,' 'when,' 'where,' and 'how' aspect of the concept under study, thus who is generating e-waste, what are the problems likely to result due to poor e-waste management, where is the e-waste dumped and how. These were some of the questions that were answered.

The design that was employed herein has advantages as well as disadvantages. The advantages include the fact that it was easy to conduct since data was fairly easy to collect and interpret especially with SPSS and excel. The data was easy to present on table, graphs and charts and could be converted into more statistical calculations that made it even clearer and easy to understand. It did not require difficult computations. The data could also be presented in its raw state from direct quotations which were captured on a recorder especially from subjects who had no problems with the recordings since it made sense and gave a clearer picture of the subject under discussion.

Despite the advantages of the design, it is important to note that the design was also vulnerable to two sources of error which are common in research and are fakery and inaccuracy. Charles, (1988) indicated that "fakery refers to informants unintentionally supplying bogus information and inaccuracy as a situation when people get facts confused, thus time obscures issues; no two people see a given situation in exactly the same way." The problems of fakery and inaccuracy were dealt with by cross-checking primary data and secondary data with publications such as E-waste management in Sub-Saharan Africa: A Systematic Literature Review by Maphosa and Maposha (2020), E-Waste Management in Developing countries – with a focus on Africa by Schluep (2010) and others on e-waste management for cities similar to Harare. The researcher also explained and emphasized the need for respondents to be honest and provide accurate information, this was fortified by a clearly defined ethics approach in which the subjects were given a choice to drop whenever they felt like and issues to do with confidentiality were also upheld.

Triangulation of qualitative and quantitative designs was employed to bring clarity about e-waste management in Harare, Zimbabwe. The quantitative design comprised of laboratory testing of soil and water samples as well as the statistical testing of SPSS and questionnaires. The collection of data was done over 6 months from May to October 2019. This was done by the researcher with the help of an assistant and four laboratory personnel and experts from the EMAL.

## 3.4 ONTOLOGY

There exist three distinct positions through which knowledge in the social world can be constructed. These are, namely: Idealism, Realism and Materialism (De Vos, 2002). Realists argue that there exists an external reality which exists independently of people's beliefs or their understanding of it. Materialism school supporters believe that there is a real-world, but that only material factors like economic factors hold reality. In this study, the researcher adopted the idealism point of view which states that reality is only knowable through the mind of respondents and therefore, is socially construed. This world-view borders well with studies that are either purely qualitative or predominantly qualitative and which seek to understand how human beings give meanings to their everyday experiences (De Vos, 2002).

Interpretive researchers believe that reality consists of people's subjective experiences of the external world. As such, they may adopt an inter-subjective epistemology and the ontological belief that reality is socially constructed. According to Willis (2008) interpretivists are anti-foundation lists, who believe there is no single correct route or particular method to knowledge. They attempt to derive their constructs from the field by an in-depth examination of the phenomenon of interest.

### 3.5 RESEARCH PHILOSOPHY

Research philosophy relates to the development of knowledge and the nature of that knowledge (Mackenzie and Knipe, 2006). In this research, pragmatism was used to guide this study. Pragmatism is regarded as the philosophical partner for the mixed methods approach. It provides a set of assumptions about knowledge and enquiry that underpins the mixed methods approach and which distinguishes the approach from purely quantitative approaches that are based on a philosophy of (post) positivism and purely qualitative approaches that are based on a philosophy of interpretivism or constructivism (Cresswell, 2013; Mackenzie, and Knipe, 2006).

Recently, mixed-methods research has attracted much attention. This is because it can help in achieving integration between quantitative and qualitative data/findings (Cassell *et al.,* 2005; Boyd *et al.,* 2012; Johl *et al.,* 2012; Zattoni *et al.,* 2013). This study adopted the explanatory sequential mixed-methods approach to research. It initially focuses on the quantitative data because of the nature of the research problem and research questions (Zattoni *et al.,* 2013). Thereafter, on obtaining statistical findings, the study explores deep insights from interviews using a thematic analysis approach.

The interview data helps in improving the quantitative findings of the study by providing additional scope for analysis to explore the effectiveness of e-waste management strategies, increases the robustness, of the empirical findings obtained from the quantitative approach (Saunders *et al.,* 2016). Interviews provide in-depth insights in the search for vital considerations for an effective e-waste management model which arguably cannot be developed through the quantitative analysis (Johl, Bruce and Binks, 2012). The argument propounded by Zattoni *et al.,* (2013) is that quantitative data alone cannot provide sufficient explanations of findings obtained through statistical analysis. Quantitative analysis does not offer a detailed interpretation and Cresswell (2011) pointed out that such interpretations are less likely to shed light on "why" a social phenomenon occurs. To further provide credence for the adoption of the pragmatism approach, Boyd *et al.,* (2012) and Molina-Azorin (2012) postulated that pragmatism permits more reliable and credible findings than any single method.

## 3.6 RESEARCH APPROACH

The study adopted the mixed-method approach (pragmatism). Interpretivists argue that reality is socially constructed, unstable and is always negotiated within cultures and social settings (Creswell, 2013; Kafle, 2011). It is for this reason, that the study deployed both quantitative and qualitative research methods together with personal interviews. Qualitative research looks for the depth of insights and is concerned with lifestyles, situations and lived experiences. Conversely, quantitative research places emphasis on using formalized standard questions and predetermined response options in the questionnaires or surveys administered to a large number of respondents (Saunders, 2011). This approach can also be described as one that generates important data obtained by the researcher from people's experiences and perceptions (Rubin and Babbie, 2001). It helped the researcher to understand how the individuals interviewed expressed their experiences and feelings while also paying attention to observable actions or behaviour (Maree, 2012).

Therefore, phenomenology is based on philosophical doctrines of what the world is like and how it can be known. It also suggests that reality is derived from an individual's experience (Kafle, 2011) and it is dialectic and interpretive (Creswell, 2013). Describing phenomena and their essence have always been the goal of phenomenology, where meaning structures of lived experiences or the life-world are core (Cresswell, 2013; Pitney and Parker, 2009; Ritchie and Spencer, 2002, Smith, Flowers,& Larkin, 2009). Thus, the purpose of a phenomenological approach is to identify and illuminate phenomena through how they are perceived by actors in a situation (Kafle, 2011). Thus, phenomenologists assume that knowledge is achieved through interactions between researchers and participants (Reiners, 2012; Smith *et al.,* 2009).

Wilson (2015) is of the view that in a phenomenological study, both descriptive and interpretive positions are legitimate and often overlap. As such "….reality is best accomplished within a natural setting where the researcher is deeply engaged with the phenomenon of interest and where nothing is taken for granted….."(Smith *et al.,* 2009). Interpretation thus depends on what the respondent says and the researcher's meaning-making (Wilson, 2015). From Wilson's line of thinking, meaning is embedded in feelings, practices and recognition. Therefore, this study adopted a similar stance to explore vital considerations for developing an effective e-waste management model. However, the weakness of such an approach is that it engages a small sample while volumes of data are collected from the respondents (Mackenzie & Knipe, 2006). The analysis of data collected is also intense (Reiners, 2012; Wilson, 2015) but leading to knowledge generation.

The weakness of the quantitative research methodology were compensated by the use of the qualitative methodology. Saunders, (2016), opined that the quantitative method proposes to measure and analyse causal relationships between variables within a framework of free values. It is based on positivism that supports empirical research since it is founded on the principle that all phenomena can be reduced to empirical indicators that represent the truth.

## 3.7 SOURCES OF DATA

Both quantitative and qualitative data was used. The primary data was extracted from the field of study in their raw state and this first-hand information was obtained using questionnaires, interviews, observation methods and laboratory experiments.

Secondary data was obtained from the Harare City Waste Management department, Public Health department, Dumpsite Office records, Ministry of Environment, Water and Climate, ZEMA, Ministry of Local Government and National Housing, Ministry of Health and Child Welfare, ZINWA, Harare Residents Association, Ministry of Information Communication Technology and several other entities. Additional information and data were also derived from government and council Acts, policy documents and published national statistics. Relevant primary sources comprising unpublished research, private correspondence and conference proceedings as well as secondary literature constituting information available in the public domain, for example, published books, journals on e-waste management in Harare, were read and reviewed to better comprehend, analyze and interpret primary data obtained from the field.

## 3.8 POPULATION AND SAMPLE

This section highlights the target population and sample size used in the study.

### 3.8.1 Target population

Population is the total number of individuals or objects being analysed or evaluated (Creswell, 2009; Saunders & Lewis, 2009; Saunders, 2011). Creswell (2013) points out that two different dimensions exist when looking at the research population. These are target population and accessible population. The target population is defined by the same scholar as being the entire cluster of elements from which the researcher would like to derive generalized conclusions and accessible population as that part of the population which is a sub-set of the target population from which the researcher would like to draw a sample from and apply their conclusions. The target population for this study were the government departments such as the Ministry of Environment, Water and Climate, ZEMA, Ministry of Health and Child Welfare, Ministry of Local Government and Public Works, ZINWA, Ministry of Industry and Commerce, Ministry of Information Communication Technology and other potentially fertile data areas on the topic that was under scrutiny, regional and international institutions such as ILO, UNESCO, World Health Organization (WHO), other research institutions, electronic gadgets manufacturers and any other appropriate and essential available literature.

For the quantitative part of the study, soil and water samples were collected for laboratory analysis. The gathered samples of soil and water totalled 33 composite soil samples and 15 water samples were taken to the EMAL for analysis. The analysis of soil and water samples was guided by local, regional and international standards such as the regulatory limits set by the United States Environmental Protection Agency (USEPA) on the maximum concentration of heavy metals in mg/kg or ppm. Also, of use were local standards by the Standard Association of Zimbabwe (SAZ) and Statutory Instruments (SI) on various environmental issues as administered by the ZEMA.

### 3.8.2 Sample size

A sample is defined as a group of respondents drawn from a population to act as a representative of the whole (Silverman, 2011). There is no clear cut answer as to how large a sample for research should be (Cohen, Manion, & Morrison, 2013). However, the sample size depends on the purpose of the study and the nature of the population under study (Cohen *et al.,* 2013). For a qualitative study, the sample size can be unlimited until saturation point (Nastasi, Hitchcock, & Brown, 2010). It is necessary to consider a larger sample size as it gives greater reliability (Strydom & Delport, 2002).

For the qualitative research aspect of the study, intentional sampling to gather information from those respondents whose information was crucial to the study and which no one else could provide was done. The total sample size from the civic and public sectors was thirty (30). According to Nastasi *et al.,* (2010) and Maree (2012), a sample of 30 is an ideal number for PhD studies. For the study, these were selected from the Harare City Waste Management Department and several other government departments, such as the: Ministry of Environment, Water and Climate, ZEMA, Ministry of Health and Child Welfare, Ministry of Local Government and Public Works, ZINWA, Ministry of Industry and Commerce and Ministry of Information Communication Technology. From institutional and civil society participants sampled were from the: ILO, UNESCO and World Health Organization (WHO), electronic gadgets manufacturers, members of the public, householders, motorists, shop customers, informal recyclers, electronic goods selling shop-owners and formal recyclers at the dumpsite, Pomona. In all, 270 other respondents and 30 targeted respondents were consulted. Interviews were held when individual participants were free. Voice recordings were taken for those who had no problems being recorded. Interview sessions were recorded to ensure that all information was captured. The information obtained was used to corroborate as well as a reference point for issues raised by other forms of data gathering tools. Thereafter recordings were descriptively analysed and transcribed.

For the quantitative part of the study, questionnaires were used to solicit answers from respondents, and also soil and water samples were collected for laboratory tests. The gathered samples of soil and water totalling 33 composite soil samples and 15 water samples were taken to the EMAL for testing and analysis. Questionnaires were administered to 270 respondents from members of the public. These included motorists to whom 70 were handed out, householders, who received 100 and others who received 100. The feedback was then analysed using Statistical Package for Social Scientist (SPSS) and excel. The analysis of data described and summarised data, identifying relationships between variables and presenting these in graphical and tabular form. In cases where critical issues were observed, photographical presentations were made and descriptive explanations were attached thereto.

### 3.8.3 Sampling procedure

Sampling concerns itself with the estimation of a population's characteristics through the selection of a subset of individuals from within the statistical population (Babbie, 2007; Denscombe, 2014; Sekaran & Bougie, 2016). It is a technique for selecting an appropriate sample for the aim of determining the characteristics of the whole population Saunders, (Saunders,2011). The elements which are selected through sampling allow a researcher to make inference and conclusions about the greater population.

There are two sampling techniques from which the researcher could choose from. These are the probability or representative sampling and non-probability or judgmental sampling methods (Gerrish & Lacey, 2010; Kothari, 2004; Walliman, 2010). Probability sampling techniques include simple random, cluster, systematic and stratified sampling technique. However, the statistics obtained using probability sampling techniques usually are used in research studies that aim to produce a statistically representative sample that is favourable for hypothesis testing. As such, they are best suited to quantitative research studies. Non-probability sampling techniques are mostly advocated for in qualitative research studies.

For the quantitative part of the study, the population was divided into several parts called quotas and, to avoid bias of sampling, some randomization technique was used to ensure that each individual in the population had an equal or known chance to be included in the sample. Since the views of every stakeholder are important the citing followed a random sampling technique to minimise bias. Bias result from a systematic error that distorts results, this would be statistical bias, participants' bias, sampling bias, non-sampling bias or bias introduced by the researcher. Also, the study followed a stratified random sampling technique so that each group of key stakeholders is well represented. It should be noted that the respondents chosen, were disproportionally identified.

The adoption of these probability or random sampling and purposive sampling technique is premised on the idea that the sample chosen should reflect the characteristics of the entire population. This means that the sample statistics must be close to the entire population parameters. By so doing, the sampling error is minimised, estimation confidence is improved, hence improving efficiency.

Soil sampling was done using systematic or stratified random sampling. The dumpsites were divided using squire grids and samples were then collected from each cell using the random selection procedure. An Auger-bit was used to take samples from soil and uniform samples in terms of amount and depth were ensured.

Despite the superiority of the random sampling technique stated above, this study also adopted a non-random or non-probability sampling technique in the form of convenience sampling where participants were chosen based on ease of access particularly the public participants. This helped to minimise costs although these were chosen at random. This was also done in line with area sampling to get diverse views from people in different geographical locations. This enables triangulation of responses and ensures validity, reliability and replicability of the study results (Bryman, *et al.,* 2007).

A random sampling method was employed to administer questionnaires to households, members of the public, recyclers of e-waste, people repairing electronic goods and other important players in the Harare e-waste management system. Questions to do with electronic gadgets, awareness of risks surrounding e-waste, recycling of e-waste, as well as disposal mechanisms, were asked. It covered a total of 270 respondents. This is because the size is within the acceptable sample size set as the rule of thumb for primary research.

For the qualitative part of the study, probability sampling was used. Probability sampling is based on the fact that every member of the population has a known and equal chance of being selected (Bryman & Bell, 2013). The study engaged a purposive sampling technique. Purposive sampling which is defined by Saunders (2011) as a sampling technique in which sample elements are chosen because they satisfy certain criteria would be employed first. Purposive sampling is commonly used for most qualitative and phenomenological studies (Oberg & Bell, 2012). Respondents were allowed to take part in the study after consenting. Purposive sampling was used to identify professional information in various government departments, parastatals and the local authority. The identified technocrats were individually interviewed. The interviews covered issues to do with environmental management laws. These included, but were not limited to e-waste generation, dumping of e-waste and possible measures to poor e-waste management, recycling of e-waste, hazards of e-waste and other aspects. Semi-structured interviews were employed in this case as they provided divergent ideas on e-waste management.

A total of 30 individuals were interviewed and these were from various departments and ministries dealing with environmental management, importation and manufacturing of electronic good. The data gathering process was spread over 6 months. The crux of how this project was undertaken is explained in the research design.

### 3.8.4 Pilot testing of Research Instrument on the Population

A mini version of the full study, also called a feasibility study or pre-testing of mainly the data gathering instruments, was done on a small number of the population beforehand. This was done to avoid pitfalls surrounding the instruments during the main research. A multiplicity of aspects was checked. These included checking the questions to be asked to see if they answered the objectives of the research. In this way, the research focus was to be maintained by keeping the questions in focus. At the end of pre-testing, some questions were removed, in particular those that did not attend to the objectives and main aim of the study.

After the changes of various aspect, all the changes to the instruments were effected. The pilot testing was personally conducted by the researcher. Participants of the pilot survey did not participate in the actual research. Critical research aspects such as body language and time allotted to each question were observed and used to re-craft some questions. The process also gave the researcher the confidence and experience needed to conduct action research in Harare.

## 3.9. DATA COLLECTION INSTRUMENTS

Wilkinson and Birmingham (2003), defined research instruments as tools used to measure and obtain relevant data to the understudy research from the research participants. The research employed the use of questionnaires, interviews, observations and experimental techniques in gathering data. Using more than one method in gathering information is the most prudent procedure to have unbiased data (Cohen, Minion and Morrison, 2011).

### 3.9.1. Questionnaire

The study used questionnaires in gathering quantitative data. According to Tuckman, (1978) a questionnaire is a document containing questions designed to solicit information appropriate for analysis. A questionnaire is a research instrument consisting of a series of questions and other prompts to gather information from respondents (Miles, Huberman and Saldana, 2014). Cohen, Minion and Morrison, 2011) asserted that a questionnaire should make it possible to translate research objectives into specific questions while answers to such questions will provide data for hypothesis testing. Miles, Huberman and Saldana (2014) noted that questionnaires allow anonymity.

The questionnaire was divided into two sections: Section A comprising of socio-demographic attributes and Section B, questions about the research and all aspects dealing with electronic waste in Harare, Zimbabwe. During the data analysis, this researcher was of the view that socio-demographic attributes were unimportant. Consequently, their analysis was omitted. In retrospect, however, Section A should also have been analysed and the profile of respondents given. Doing so would have better provided a good contextual background of the population sample, as well as for empirical analysis. Respondents were instructed to provide answers on the spaces provided on the questionnaires. This means after the topic and introductions, participants were given instructions on how to answer the questions.

All respondents were asked identical questions. This ensured reliability of the instrument. Simple English was also used to allow easy understanding of the question by respondents of all academic abilities.

The advantage of this instrument was that it covered a large area of the population because it could be distributed to the required population by hand. Judd *et al.,* (1991) asserted that low cost is the primary advantage of written questionnaires whether mailed or handed out. Since the respondents were answering the questions independently, there was less interviewer bias to influence the answers. The respondents answered the same set of questions on electronic waste management in Harare and accurate measurement of responses were promoted (Cohen, Minion and Morrison, 2011) also observed that this has the advantage of being "an economical way of collecting a variety of information from a large number of people even though widely spread geographically." This economical aspect proved true as the economy of Zimbabwe is currently unstable. In summary, the advantage of questionnaires is given by Mc-Milton *et al*., (1993:238) who said, “a questionnaire is relatively economical, has standardized questions, can ensure anonymity and questions can be written for a specific purpose."

The questionnaire however has its disadvantages. These include among others, respondents withholding information because they do not wish to divulge it for reasons best known to themselves. It can also require respondents to give information on topics unfamiliar to them (Tuckman, 1978:196). Some respondents may deliberately leave some questions unanswered. When open-ended, such questions might be too restrictive leading to shallow responses, since respondents will be unable to fully express their views, opinions or feelings.

In cases where respondents have to mail questionnaires, for one reason or another, some will not send their completed questionnaire. In other cases, respondents interpret questions differently. For this study, such problems were avoided through triangulation. Using more than one data collection instrument allowed the researcher to cover the possible weaknesses of the questionnaire. The interviews and questionnaires complemented each other.

The questionnaires for this study were hand-delivered. The fact that the researcher was there on the ground dismissed the problem of question misinterpretation, failure to post back the questionnaire and living out some questions unanswered. The 'drop and pick' method was avoided to ensure accuracy. In the event of failing to understand the question, the researcher was there to give an interpretation even in local languages, such as Ndebele and Shona, just to make sure they understood the questions. For the illiterate, the researcher was always there to help them out with reading the question, interpret as well as writing the answers down for them, especially to those who felt they could not write but could provide answers to the questions.

The questionnaire was used to gather information on e-waste generation, from the public as well as professional views regarding e-waste in Harare, Zimbabwe. Areas of focus were, management of e-waste, disposal and dangers of e-waste to both the population and the environment, as well as legal issues surrounding e-waste in Zimbabwe. These were administered to people in general at individual and household levels. Electronic good selling shops, as well as electrical and electronic goods manufacturing companies, answered the questionnaires. Also, of note are companies and individuals who were into e-waste recycling.

A total of 270 respondents were randomly selected to answer these questionnaires. This was done in consideration of the large study population and the financial implications of the research. The population size however was within the stipulated number for primary research as justified by Haralambos and Holborn (2000) who indicated that a sample for social research should be 33.3 % of the study population. Considering the number of organisations whose input was critical for the research, 30 key informants from various entities were conveniently picked. After the data was gathered Statistical Analysis Packages such as NVivo and SPSS were then used to analyse the data, excel was also employed. This then gave birth to tables, graphs and charts presenting the information and more information to fortify this was obtained from secondary data and data collected by other instruments. Descriptive analysis was also employed in this case. The questions were done to elicit reactions on what participants felt about e-waste, beliefs and attitudes of the residence of Harare on e-waste management. The questionnaire used in this research were made to collect the same information from each respondent. All respondents were asked the same questions. This ensured reliability of the instrument. Simple English was also used to allow easy understanding of the questions.

### 3.9.2 Interviews

This study used interviews in collecting qualitative data. An interview guide was used. An interview is a conversation where questions are asked in a one-on-one conversation and answers given (Dawson, 2012). Interviews are a systematic way of talking and listening to people and are another way to collect data from individuals through conversations (Dawson, 2012). Ambiguities can be clarified and incomplete answers followed up easily as the meaning of questions simplified, (Miles, Huberman and Saldana, 2011). (Dawson, 2012).

Structured interviews were also employed. The structured interview ensured reliability since the same questions were asked. The advantages were that the researcher could further probe to get clarity on e-waste management in Harare, Zimbabwe. Ambiguous items were also modified as the interview process proceeded, although this was also dealt with during the pilot survey, administration and testing of the instruments.

The researcher was able to get first-hand information and could record non-verbal behaviour and use it in the data analysis. It was flexible and enabled the researcher to repeat or rephrase questions for respondents to understand. Face-to-face interviewing also ensured a high response rate. Lastly, it permitted the interviewer to use his discretion and to depart from the set questions as well as their order of presentation when the situation demanded. It must however be noted that respondents sometimes felt uneasy and adopted avoidance tactics on issues they perceived to be a sensitive question. Examples of such questions included whether Zimbabwe had adequate environmental legislation or not. Questions that were clear to one respondent seemed relatively opaque to the others. Also, the fact that issues of mutual trust and social distance differ from individual to individual, affected responses by different participants. Finally, this method was time-consuming since only one person could be interviewed at a time.

The problems were cured by simply explaining to respondents that the whole issue was purely academic and also explaining the same question in different ways to meet the different understanding levels of individuals. To avoid the suspicion, the researcher was formally dressed and produced identity documents to respondents to prove beyond their doubt that the work was academic and nothing else. The individuals who hold positions in government, council departments, non-governmental organizations and other offices relevant to environmental management and specifically e-waste management, were exposed to interviews purposively.

A total of 30 respondents were interviewed. These were experts from institutions such as the: ZINWA, Ministry of Health and Child Welfare, Ministry of Environment, ZEMA, departments responsible for imports and exports in the country, the local authority waste management and public health sections as well as non-governmental organizations. Consented recording of these interviews was done to ensure that important issues raised were captured. These were picked using purposive sampling.

Questions asked included e-waste management and legislation, recycling of e-waste, government policy and several other relevant issues on e-waste management in Harare, Zimbabwe. The information gathered from interviews were used to verify findings from other forms of data gathering and some statements were directly quoted for purposes of descriptive analysis. The interviews helped to derive information that could not have been captured by other methods. This helped to cross-check the information provided by other relevant stakeholders. Some of the key respondents were drawn from organizations listed below as well as information that was sought.

Table 3-2: Organisations from which interviewees were selected

| No | ORGANIZATION | INFORMATION SORT |
|---|---|---|
| 1 | Zimbabwe Environmental Management Agency [ZEMA]. | E-waste law and environmental management in general as well as specific e-waste management plans and recycling |
| 2 | Ministry of Local Government and National Housing | E-waste management in Harare as well as dumpsites issues, administration of such and possible plans. |
| 3 | Ministry of Environment, Climate and Water | Environmental management with specific reference to e-waste, available legislation on e-waste and recycling and management mechanisms of e-waste. |
| 4 | Zimbabwe Environmental Lawyers Association | The environmental law and e-waste. |
| 5 | Ministry of Health and Child Welfare. | Health issues and waste management especially e-waste and associated diseases |
| 6 | Greater Harare Residence Association | Residence position with regards to e-waste management in Harare |
| 7 | National Social Security Authority [NSSA] | Safety in the informal sector particularly e-waste recyclers at the main dumpsites and those involved in repairing e-good returned by customers in local electrical and electronic goods selling shops. |
| 8 | Harare City Council [HCC] | Waste management and public health issue regarding e-waste in Harare, E-waste dumping, Recycling and licensing of recyclers as well as monitoring of such. |
| 9 | Zimbabwe National Water Authority [ZINWA] | Heavy metals in water, most importantly in sources that supply the city of Harare with water for domestic use |
| 10 | Zimbabwe Revenue Authority | Amount of electronic goods entering the borders of Zimbabwe |

| | | |
|---|---|---|
| | [ZIMRA] | |
| **11** | Zimbabwe Electricity Supply Authority [ZESA] | Electronic waste and the role of the organization in the management of electronic waste |
| **12** | Zimbabwe Informal Sectors Association [ZISA] | The problems associated with e-waste recycling and the role of the organization in the recycling of such |
| **13** | Ministry of Industry and commerce | The law in connection with the importation of electronic goods |
| **14** | Dstv Zimbabwe | Their take back policy |
| **15** | Postal Telecommunication Regulatory Authority of Zimbabwe [POTRAZ] | Number of mobile subscribers and well as their role in the management of e-waste |
| **16** | Pomona Dumpsite Foreman | Control of waste how it is deposited at the dump, general management, recyclers and their role, waste separation and the monitoring of dangerous elements at the dump and its surroundings |
| **17** | Harare city health department | The number of cases related to e-waste diseases reported to them as well as their education policy. |

Source: Field Survey, (2019).

The researcher was able to get first-hand information and could record non-verbal behaviour and use it in data analysis. Face-to-face interviews also ensured a high response rate. The majority of the interviews were audio-recorded. Table 3.2 above captures some of the organizations from which people were interviewed. It must however be noted that not all were captured in Table 3.2 above for different reasons like others feeling the information required was sensitive and opted for anonymity.

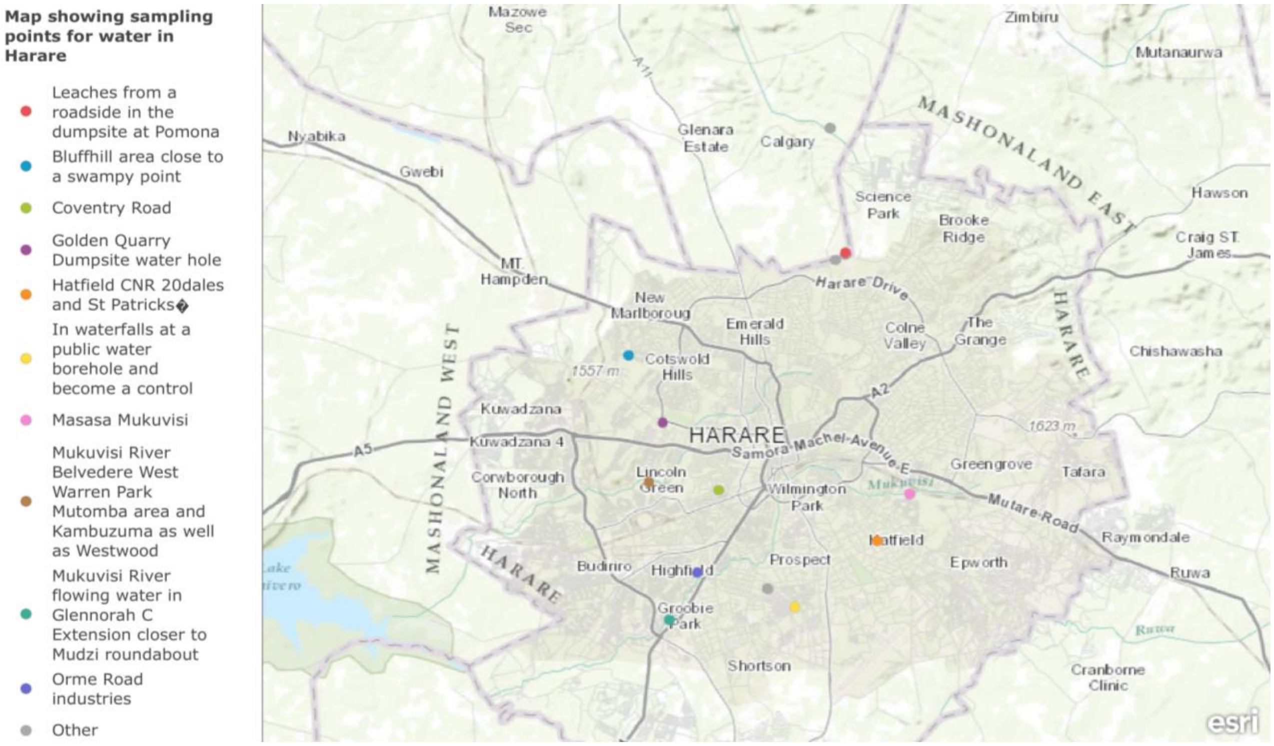
### 3.9.3 Laboratory Testing

Soil and water samples from the main dumpsite and areas around dumping sites were taken for laboratory testing, including water from rivers passing through or close to Harare, and most importantly, rivers passing close to dumpsites. Global Positioning System (GPS) was used to pick various points from which these samples were taken. Thirty-three (33) composite soil samples were randomly collected at a depth of 0 – 30 cm from around Harare's main dumpsite, Pomona. Sampling points were selected using the stratified random sampling method in a grid manner and were chosen based on specific characteristics such as proximity to water sources and distance from the main official dumpsites. In each area, samples of soil and water were collected twice per month from different points within the same area and three times a month at the main dumpsite. An average of these two samples then represented results for that month. Monthly collections were done continuously for six months.

The results were analysed quantitatively using SPSS. The 33 soil samples were composite samples collected at different points and intervals in each area. The soil samples were then air-dried and sieved through a 2.00 mm mesh, weighed and then digested with aquilegia to get the materials into the solution for reading. Five other randomly selected roadside and or open land dumpsites in industrial and residential areas were also sampled. From each area, the samples were taken twice per month. This brought the total soil samples to be collected in Harare to 33 composite samples. Each sample weighed 500 grams. The soil was labelled hazardous if it showed characteristics of lead, cadmium, mercury and chromium toxicity that were 100 mg/kg or more. This means contaminants exceeding acceptable levels.

A total of 15 water samples were collected from various water sources in Harare. From the Mukuvisi River, water samples were drawn from the upper, middle as well as downstream. The second set of water samples was also obtained from wells in some illegal and yet to be planned settlements in the Waterfalls Retreat area of Harare. The third from leachates within Pomona dumpsites as well as a water hole at the Golden Quarry dumpsite. Sample containers for water, were thoroughly cleansed filled with water for a day to remove water soluble materials from the container. The bottles were plastic and resistant to impact and internal pressure. The sample container tops were cleaned and a plastic was added to ensure no leakages. Sample collection and position coordinates, sample name and collection time were also recorded. Below is a map showing some of the areas from where water samples were collected.

Figure 3.3: Water Sampling Points.




Sources: Primary Data, (2019).

The coordinates to the water sampling points are tabulated in Table 6.1 in Chapter 6. The water was collected in clean 2-litre plastic containers that had been disinfected with liquid soap and rinsed out several times. At the collection point, the containers were again rinsed three times with site water before the collection of the final sample which was then labelled. The collected samples were then delivered to the laboratory within 24 hours of collection. Pre-lab preparation comprised labelling and ensuring that the containers and sample bags were clean. The testing and analysis were done at the EMAL as guided by Statutory Instrument number 6 of 2007 and other regional and internationally acceptable standards such as the WHO standards.

The laboratory tests were done in the presence of the researcher who, in this case, was a guest observer. The researcher was first informed of the several processes and methods of preparing the samples for analysis. Thereafter, once the researcher had comprehended the process, he and the laboratory personnel were both given Personal

Protective Equipment (PPE) to protect them from any possible Covid-19 infection and other laboratory dangers. This done, the requisite laboratory rules were outlined to them. All the samples were then analysed in the researcher's presence.

### 3.9.4 Water and soil (Hg & As)

For water samples, one (1) ml of hydrochloric acid was added to a volumetric flask then topped to the mark with 99 ml of sample. This was done for all the water samples for mercury (Hg) and arsenic (As) analysis. Samples were analysed using the GBC Atomic Absorption Spectrometer Hydride Generator Cold Vapor method for Hg and Flame Atomic Absorption method for As. Soil samples were oven-dried at 105$^{o}$C for more than an hour. Samples were let to cool to room temperature then ground using a pestle and mortar. Samples were sieved then a 10g sample weighed for digestion with hydrochloric acid for 2 hours on a mechanical shaker. Digested samples were then filtered into a 100 ml volumetric flask collecting the supernatant. Distilled water was used to fill the volumetric flask to the mark. The digested water samples were then analysed in the same manner as water samples no HCL was added to the samples as the HCL was the digestion solution. For all chemicals and reagents, Merck NIST traceable standards and reagents were used. The GBC Savant AA (Atomic Absorption Spectrometer) and GBC HG 3000 Hydride Generator were used in the testing of mercury and arsenic. The machine is a product of GBC Scientific Instruments at ZEMA and it is serviced every six (6) months.

### 3.9.5 Observations

To Best and Kahn (1993), site observation is a characteristic of descriptive research. Lexically defined, it is the action or process of watching someone or something carefully, to learn something through observation. In this study; on-spot observations were carried out to reinforce and validate information obtained from interviews. For example, e-waste dumped by the roadside in Harare, and vegetables that are grown along and watered using the heavy metal polluted water from the Mukuvisi River. These observations were photographically recorded and a descriptive explanation given. Common aspects were looked for during the observation to ensure the validity of the exercise then listed on an observation checklist. The advantages of the observations are that firstly, they captured a correct record of what was happening. Secondly, the information they provided could be used to corroborate facts given by all the consulted respondents. Thirdly, it validated the information obtained in the interviews and questionnaires. Lastly, the exercise provided the researcher with practical evidence as opposed to solely depending on oral and written reports.

However, the method also has its limitations. For instance, it can be manipulated to subjectively reflect a researcher's insights and understanding. The observations demanded the physical presence of the researcher. As such, the researcher had to take time to observe activities, which at times was tiresome. Albeit such challenges, the researcher objectively and diligently focused on the observation tasks to ensure accuracy.

Visible e-waste dumps were selected for observation. Practical evidence was generated and photographic evidence was shown. This gave some fortification to data obtained by other methods. Guidance on what to focus on was from an observation checklist. The checklist confined and directed the researcher on what to look for and avoid going astray. Generally, observations enabled the researcher to see the kind of electronic waste dumped, areas where this was commonly done, proximity to water sources, human settlements as well as evidence of burning of e-waste and other important aspects. Coordinates were picked for such e-waste dumps for further analysis and presentation, thus giving a clear visual picture of the state of e-waste distribution in Harare, Zimbabwe. A primary source of data as defined by Best (1970) is an "eyewitness account or report by an actual observer or participant in an event." This primary data was extracted from the field of study, Harare, Zimbabwe in its raw state and this first-hand information was obtained using questionnaires, interviews and observation methods.

### 3.10 DATA COLLECTION AND ORGANISATION TECHNIQUE

This section presents the data collection techniques employed by the study**.** Sirikaya-Turk, Uysal, Hammit, and Vaske (2011), postulated that data collection refers to those activities which are designed to determine what makes data for a particular field of study, who or what to gather the relevant data from and the techniques to be used for gathering such data. Permission was sought from relevant ministries first in writing. This section focuses on how gathered data is to be organised, analysed and presented.

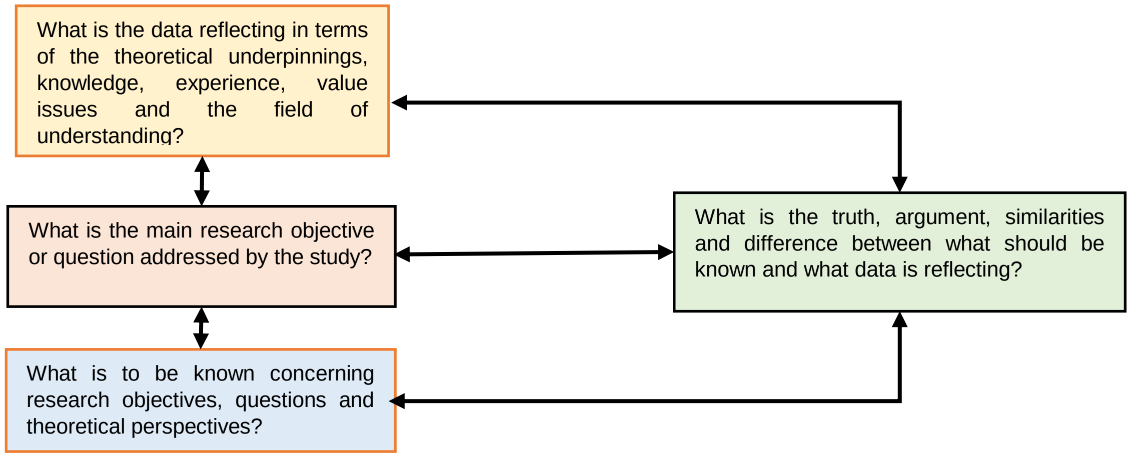
### 3.10.1 Presentation of data

Results from the analysis of data were presented in Chapters Four, Five, Six, Seven and Eight of this Thesis. Research questions guided the data presentation process. Data was presented in themes augmented by descriptions and explanations. Braun and Clarke (2014) suggested that data can be presented in terms of a storyline, a map, or a model, a table or a figure. The emerging themes can be networked into patterns and configured into thematic trees. Observations from the field were used to augment findings. Data sources, research respondents' voices and the generated themes were used to provide an informed presentation. Coding was used also to identify themes and patterns across themes.

### 3.10.2 Framework for Data Analysis

This study's framework for data analysis was adapted from the works of Srivastava and Hopwood (2009) who contend that in research, a framework for data analysis relates to the questions that one uses to address a research problem at hand. The scholars are of the view that iteration is important if one wants to gain meaningful insights from the data as it is useful in clarifying concepts. Srivastava and Hopwood (2009) argue that an answer to one research question also shapes the other questions to be addressed leading to the refinement of the major research question's focus and the integration of data. Thus, this study was guided by different open-ended questions from the in-depth interviews which were augmented by observations to fill in gaps identified during the literature review process.  Figure 3.4 below shows the framework for data analysis.

Figure 3.4: Framework for Data Analysis



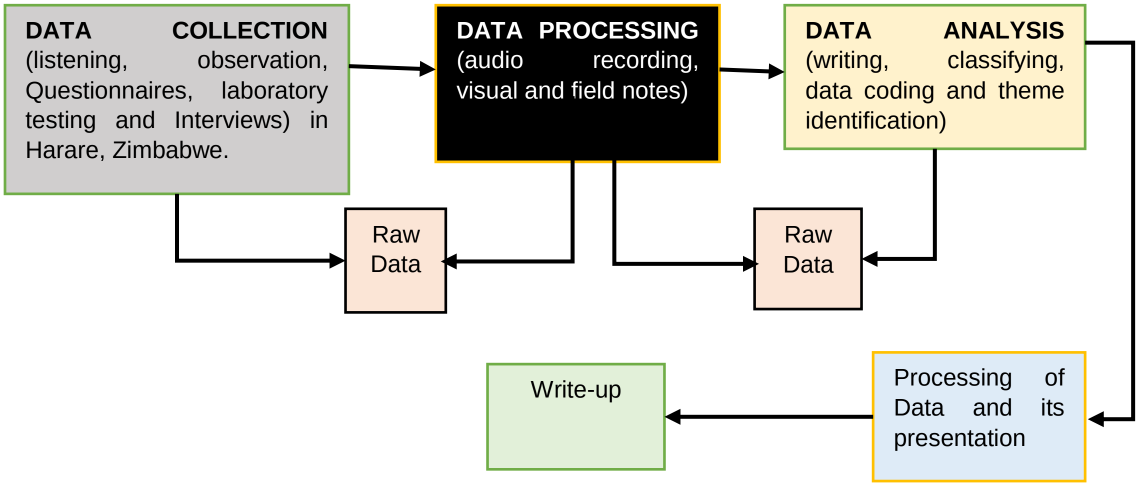

Source: Adapted from Srivastava and Hopwood, (2009).

The above framework was used in this study to guide the data analysis process. Four major questions were considered in this study's data analysis as indicated above.

### 3.10.3 Data Analysis Strategy

Thematic analysis is an ideal strategy for data analysis in this study. This method has been used in most qualitative studies. The method was noted to possess variations and flexibility in its analysis process giving room for creativity (Braun & Clarke, 2014). It seeks to expose salient themes in textual data at diverse levels. However, Braun and Clark (2014) stated that thematic analysis is an analysis process that involves the establishment of themes through reading and re-reading of recorded data resulting in the identification of patterns within a data set. It is inductive hence it systematically connects text with content (Fereday & Muir-Cochrane, 2006). This was diagrammatically presented as shown in Figure 3.5 below.

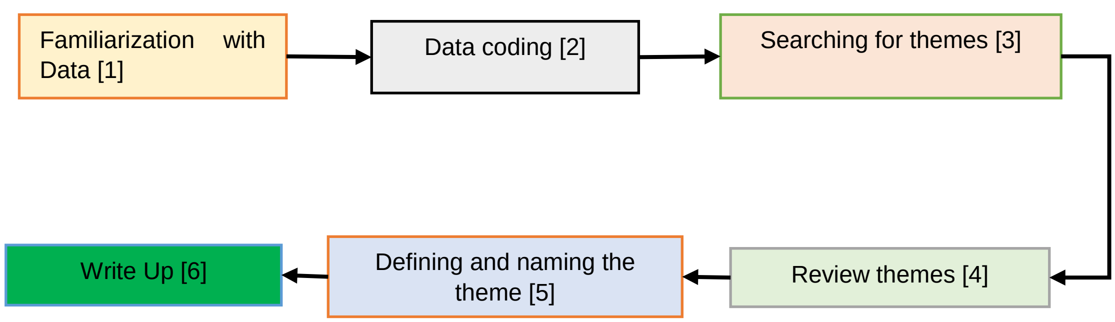
Figure 3.5: Qualitative Data Analysis Steps




Source: Adapted from Braun and Clarke, (2006).

The present study used thematic analysis to assess e-waste management in Harare. Transcribed data were analysed for emergent themes from the respondents' statements to describe their related experiences. In this regard, this study utilized the data analysis technique from Braun and Clarke's (2014) six phases of data analysis. Figure 3.6 below summaries Braun and Clarke's stages of thematic data analysis.

Figure 3.6: Six stages for Thematic Analysis




Source: Adapted from Braun and Clerke (2006)

After familiarisation with the data collected from participants axial and selective coding was utilized to comprehend the phenomenon under study. Open coding was done to break data into discrete parts and create codes on critical e-waste issues such as recycling, dangers of e-waste and others to enable comparison and contrast similar e-waste issues in the data. Axial coding helped draw connections between the codes generated in open coding and finally selective cording then connected all e-waste issues together. Axial coding considers the research objectives in the process. Selective coding allows the analyst to identify variable themes, concepts, isolate relationships and patterns, identify similarities and deduce differences for informed conclusions from data presented. Themes and sub-themes were generated in the process and were described to reveal their meaning and importance. Excel spread sheet and NVivo were employed in the sorting and organising of the data. In order to provide rigour to data analysis, the researcher beside manual theme development also sought the help of computer software packages. There are a variety of Computer Assisted Data Analysis Software (CAQDAS) at the disposal for researchers doing qualitative research studies. This study adopted NVivo as the data management software. An attempt was also made to use NVivo to analyse data in a bid to augment the data analysis process by Braun and Clarke, (2006). This software managed to identify references to phrases and codes but it did not discern different contexts and neither did it interpret data. However, the use of NVivo as a data analysis software had its own limitation. The major limitation was that it distanced the researcher from their data as observed by Wilson, (2015). As a result, the data were manually analysed. The manual analysis technique helped to retain all the data that helped to address the study objectives. This analysis technique assisted the researcher to own much of the data and to use it at own discretion.

Coloured pens were used in the analysis process where a colour represented a code. Blue, yellow, red, green and purple colours were used. The blue colour was used to highlight data that highlighted the electronic waste management (e-waste) strategies being used in Harare. Yellow was used to mark any data that reflected the existing environmental laws in relation to electronic waste management in Zimbabwe. Red represented any data to do with the effectiveness of available electronic waste management strategies being used in Harare. The green colour highlighted data that illuminated the population of Harare's understanding of the phenomenon of e-waste management, while purple colour represented data to do with strategies for effective electronic waste management for Harare.

### 3.11 DATA PRESENTATION AND ANALYSIS PROCEDURES

The purpose of data analysis is to obtain useful information that can be exploited to achieve the intended goals (Creswell, 2013). In simple terms, it is about what the collected data is reflecting or reporting. In this study, therefore, data analysis was expected to illuminate the phenomenon under study. The analysis process was used to predict the results of the study and to identify apprehensible ways of presenting the findings, as well as to conclude.

The data that was obtained using the various collection methods were tabulated and figures were expressed in graphs and charts. Photographs were also used to present the information and in general to show e-waste dumped across Harare and the state of affairs at the two Harare official dumpsites, namely: Pomona and Golden Quarry dumpsites. The data was then analyzed relative to the initially started research question and literature citations in chapters one and two. The obtained data was graphically and photographically presented, as well as being tabulated and also being statistically presented in percentages. All these helped explain the main objectives under which the research rested.

The presentation and analysis were done in the simplest way possible to ensure easy comprehension of the information collected. For an overview of the distribution of e-waste and associated heavy metals around Harare, several maps of the City have been presented in Chapter Six (6).

#### 3.11.1 Results Analysis, Validity and Reliability of the Research Findings

Results of independent samples were collected and analysed descriptively and quantitatively using SPSS. The data collected using questionnaires was also captured and analysed, both descriptively and quantitatively. Electronic management laws, electronic waste disposal and health hazards of electronic waste were analysed descriptively, since they were partially based on respondents' perception. However, statistical relations between some variables such as availability of electronic goods, household sizes and presence of heavy metals were analysed using SPSS. The disadvantage of this is bias. Despite this, the researcher did everything to come up with unbiased results. Validity and reliability are two fundamental elements in the evaluation of a measurement instrument concerned with the extent to which the data collected is a true reflection of what is being studied (Miles, Huberman & Saldana, 2011). Creswell (2013) opined that validity is concerned with the extent to which data collected is a true reflection of what is being studied.

### 3.11.2 Validity and reliability of questionnaires

According to De Vos, (2002), the idea of pilot testing is "to see if the beast will fly". This means that before anything is done with regards to the critical review of e-waste management in Harare, the researcher had to check the interview questions and questionnaires and other instruments, to ascertain that they are fit for the project and will help gather the required information without leaving out critical issues, breaking ethical rules of the research as well as establishing time issues in case the instrument is too long and might cause problems during the actual research work. This was done for this research. The main aim of this being to avoid pitfalls.

To ensure content validity, the researcher pilot-tested the questionnaire by administering it randomly among a sample similar to the proposed population. The Pilot survey's total population comprised of 14 individuals, 7 males and 7 females. This pre-testing exercise was meant to check whether respondents understood the questions and their relevance. Thereafter, the researcher then made some amendments to the structure of the questionnaire and question-wording based on the evidence gathered from the pilot test.

Multiple aspects were checked and these included the checking of the questions to ascertain whether they answered the objectives of the research. The research focus was to be maintained by keeping the questions in focus. This meant ensuring that ambiguity is avoided, rephrasing some questions to ensure that they are in line with research objectives, checking for and removing vague terms. At the end of the pre-test, some questions were removed especially when they did not attend to the objectives and the main aim of the study.

### 3.11.3 Validity and reliability of qualitative data

Qualitative research studies have been subjected to criticism over issues of scientific rigour (Noble and Smith, 2015). The traditional measures used to establish validity and reliability are quantitative and positivist in nature. They cannot be applied in naturalistic studies (Anney, 2014; Noble and Smith, 2015). Quantitative studies often use objectivity, reliability and validity of standardized instruments to ensure the credibility of research data (Ndlovu, 2009). Establishing the accuracy of qualitative research findings is not an easy task.

According to Noble and Smith (2015), the validity of interviews is strengthened by using interview techniques that build rapport and trust. Thus, giving informants the scope to express themselves and also prompting informants to illustrate and expand on their initial responses. Leedy and Ormrod (2055) commented that another way of avoiding or at least minimizing interviewer bias, is to require all interviews to follow the same protocol. Hence, a set of guidelines might be drawn up which ask the interviewer to read the questions exactly as they are written, to repeat a question if asked, to accept the respondent's refusal to answer a question without any sign of irritation and to probe in a non-directive manner. This researcher found that the interview as a research instrument largely increases the validity and reliability of the data gathered.

However, there remain several ways in which the trustworthiness of qualitative research studies findings can be enhanced. The trustworthiness (analogous validity, reliability and neutrality in quantitative studies) of qualitative studies can be established through four strategies which are credibility, dependability, transferability and conformability (Ndlovu, 2009). Noble and Smith (2015), stated that qualitative, unlike quantitative studies where statistical methods are utilized to satisfy issues of validity and reliability of study's findings, have to incorporate methodological criteria to enhance the trustworthiness of research findings.

Credibility is defined as the extent to which collected data and the subsequent data analysis is trustworthy and plausible (Anney, 2014; Graneheim and Lundman, 2004; Holloway and Wheeler, 2002; Macnee and McCabe, 2008; Ndlovu, 2009). To achieve credibility, triangulation of data was used. Research instruments such as questionnaires and observation guide were used to triangulate the collected data. As advised by Macnee and McCabe, (2008) the researcher also included the voices of participants in the data analysis and presentation.

Transferability is equivalent to external validity in quantitative studies and refers to how research findings can be generalized to other contexts outside the actual study setting (Bitsch, 2005; Ndlovu, 2009; Noble and Smith, 2015; Tobin and Begley, 2004). The researcher provided rich and thick descriptions taken verbatim of respondents accounts to bolster the research findings (Ndlovu, 2009; Noble and Smith, 2014). Cohen, Manion, and Morrison (2011) added that purposive sampling also helps to satisfy issues of transferability in qualitative studies as it allows the researcher to focus on key respondents who are well-informed about the issues under study. Thus, the sampling technique was adopted in this study for this reason.

Dependability refers to the consistency of the findings of research over time (Bitsch, 2005; Ndlovu, 2009). It parallels reliability in quantitative studies. Cohen *et al.,* (2011), postulated that dependability entails participants' evaluative feedback on reported findings, interpretations and conclusions. To satisfy the dependability of the research findings, the researcher diligently kept records of raw data and observation notes, documents and any other records obtained from the research field (Ary, Jacobs, Sorensen, and Walker, 2013; Long and Johnson, 2000; Schwandt *et al.,* 2007). These documents were kept for cross-checking the research process.

Conformability refers to the way research findings can be corroborated or confirmed by others (Ndlovu, 2009). Conformability parallels research objectivity in quantitative studies. It accounts for the researcher’s subjectivity or bias in establishing data and its subsequent presentation. The researcher made use of the audit trail (keeping all the necessary documents, interview notes from the field). Noble and Smith (2015), support the use of an audit trail in enhancing the conformability of research findings, and so was adopted by the researcher in this study.

### 3.12 ETHICAL ISSUES OF THE RESEARCH

Research studies have to abide by a set of moral standards that ensure the dignity, safety and social well-being of participants (Punch, 2013). Stevens, (2013) outlines ethical principles in conducting research. The researcher must first seek permission from the participants and authorities. Ethics are a critical element to any standard research as research entails the gathering of information from people about people (Punch, 2013).

Permission to conduct the study was sought from all responsible authorities and boards in writing before data collection. In this case, authority was primarily granted from the University of South Africa Ethics Committee which cleared the researcher under ethics clearance number 2017/CAES/159 to undertake the research. The first clearance was followed by an ethics renewal thereof. The clearance included a written letter from the laboratory which did the soil and water tests, which in this case was the EMAL. A lot of critical concepts were looked at regarding ethical consideration and all protocols and principles were observed and these included issues to do with confidentiality, justice, anonymity, consent and other ethical issues.

The researcher observed and respected the participant’s protection rights. As such, participants’ identities were not exposed. No names were used except with the permission of the participants. In such cases, pseudo names were used. Stevens, (2013) and Braun and Clarke (2014) postulated that researchers should make sure that research participants are well informed of the research study's intended purpose, its aims, data collection methods to be employed, and the merits and demerits of participation in the study, before they decide whether to participate or terminate the association prematurely. Participants were informed about the purpose of the study and how the findings will be exploited before they were made to consent. Voluntary consent was sought before conducting the interviews and observations.

Several letters were written to various government ministries and departments and other entities such as the Harare City Council seeking authority to be allowed to interview personnel and to visit the dumpsites, as officials at the sites were to escort the researcher and introduce him to scavengers as well as give him general guidance on the site. Most departments to whom letters of requisitions were sent responded giving approval as well as defining official secrecy issues, which were strictly adhered to.

All ethical issues were taken note of to ensure the ethical acceptability of the study. The researcher sought permission to carry out the research and this was granted by all the key stakeholders such as the City of Harare, Ministry of Local Government and Public Works, Ministry of Health and Child Welfare, ZEMA and others that were directly or indirectly linked to e-waste management in Harare, Zimbabwe. Written consent was given and, in some cases, official secrecy forms signed by the researcher to ensure that no information provided was abused. These clearance letters were carried along during the data gathering process to allow officials and individuals as well as those who wanted to verify them, to do so easily.

The ethical principle of beneficence and justice was employed in the work. No names of institutions were linked to any respondents and the research report would not mention any person or any institution, thus maintaining anonymity in the report. After data analysis, submission and approval of the final document, all qualitative data collection instruments such as completed questionnaires will be destroyed by the researcher for purposes of anonymity.

## 3.13 CHAPTER SUMMARY

The chapter focused on the studies' adopted research methodology. The study adopted a pragmatism research approach as some of the objectives required statistical measurements of one variable over the other. It also highlighted the data collection techniques used which were the interview guide, observation guide, questionnaire and experiments. Data were analysed using, Chi-square analysis, statistical analysis such as percentages, laboratory tests, as well as descriptive analysis. The analysis was done with research objectives and literature citations in mind. The validity and reliability of the study were also discussed in this chapter together with the ethical considerations of the study. The next chapter will focus on the data analysis and presentation.

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# Chapter 4

## ELECTRONIC WASTE MANAGEMENT STRATEGIES IN HARARE

### 4.0 INTRODUCTION

The previous chapter focused on the research methodology adopted to address the main research question: What model can be developed for effective electronic waste management in Harare, Zimbabwe? This chapter assesses the e-waste management strategies that are being used in Harare. Specifically, it focuses on the nature of e-waste in Harare, sources of e-waste and strategies that are being used to manage e-waste in Harare. To get a holistic understanding of the phenomenon under study, the chapter starts by looking at the conceptualisation of the term e-waste from the respondents' perspective and experience.

### 4.1 CONCEPTUALIZATION OF THE TERM E-WASTE

There is no universally accepted definition of the term e-waste. Consequently, several definitions have attempted to explicate the e-waste phenomenon (Widmer *et al.,* 2005; Oteng-Ababio, 2012; UNEP, 2013; Balde *et al.,* 2017; Mandevere, 2016 and ILO, 2019;). Field findings indicate a plethora of definitions from the respondents, all attempting to conceptualise the phenomenon of e-waste. Findings from the study indicate that the respondents had a good understanding of what e-waste is. Respondents highlighted different definitions and some of the definitions are as presented in Table 4.1 below.

Table 4-1: E-Waste Definition by Different Respondents

| ***RESPONDENTS*** | ***RESPONSE*** |
|---|---|
| *Harare resident* | *This is unwanted obsolete electronic goods* |
| *Municipality of Harare official* | *Any unwanted electronic goods that are thrown away* |
| *EMA official* | *E-waste describes discarded and unwanted electrical devices and used electronics that are destined for reuse, salvage or the dumpsite.* |
| *Electronic shop owner* | *Forms of electronic and electric equipment that have ceased to be of any value to their owners.* |
| *E-waste worker* | *Electronic goods that are perceived not useful* |

Source: Field Survey, (2019)

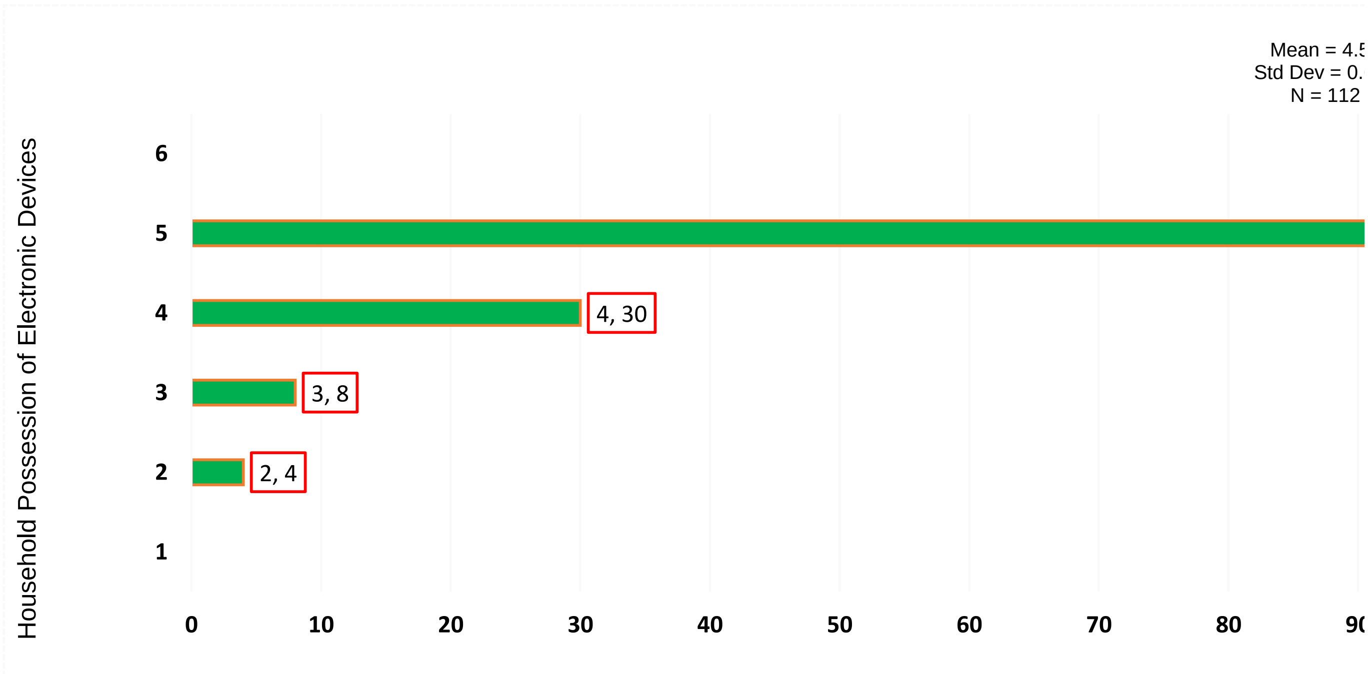
Ninety per cent of respondents thought that e-waste refers to electronic gadgets that are no longer functional or have come to the end of their purpose and so should be disposed of. Most of these definitions shared similarities with StEP Initiative, (2014) that defines e-waste as "any electrical and electronic products (household or business) with circuitry, or electrical components with power or battery supply that has reached its end of life". In this respect, the findings are in line with the literature. However, some of the responses given proved to be vague as *some defined e-waste as simply "wastes* from radio repairers" some as *"wastes such as electric toys" and others labelled it simply "electricals".* Although these definitions seem vague, a close analysis of all of them at best reveals the understanding that e-waste has to do with electrical appliances that have ceased to be functional. The respondents' conceptual difficulty with the term e-waste is akin to other writers who have defined e-waste as simply: Waste Electrical and Electronic Equipment (WEEE). Such a definition might be deemed vague and unclearly definitive of the e-waste phenomenon. The reason for such definitions may be the result of flippantly treating the issue or simply a lack of concern. This view finds support in the argument that the level of one's involvement and attachment determine one's level of commitment to answering a question.

Evidently, as Amuzu, (2018) highlighted, the multiplicity of what constitutes WEEE poses, a waste classification challenge as several forms of WEEE which may or may not be normally considered as e-waste are prevalent in literature. This as it may be, however, ninety per cent (90 %) of the respondents who took part in this study proved to be aware of what constitutes electronic waste.

## 4.2 SOURCES OF ELECTRONIC WASTES

The ownership of electronic gadgets and their eventual disposal is the main source of e-waste. Cognisant of this fact, households must curtail the number of electronic gadgets they own if sustainable e-waste management is to be a reality in Harare. The survey results confirmed the increased generation of e-waste in urban areas. More than a hundred respondents either agreed or strongly agreed that urban households own a lot of electronic gadgets. The graph in Figure 4.1 `below confirms the results.

Figure 4.1: Urban Households Ownership of Electronic Gadgets Waste




Sources: Primary Data, (2019).

Given that the urban settlements are many and have a relatively higher population density than rural areas, waste management is a big challenge in urban areas. This finding is proportionate to the 70% respondents who hypothesised that there is a strong link between the population size and electronic waste generated. Harare comparatively has a higher population than any other city in Zimbabwe (Zimstat, 2012). It, therefore, follows that e-waste generation is likely to be higher in Harare than in any other parts of Zimbabwe. Similarly, the management of e-waste has to be better organised and effective in Harare and these other urban areas if the hazards associated with e-waste to both humans and the urban environment are to be minimised. This can be achieved by putting in place proper recycling, reusing and reducing and other environmentally sound e-waste management systems.

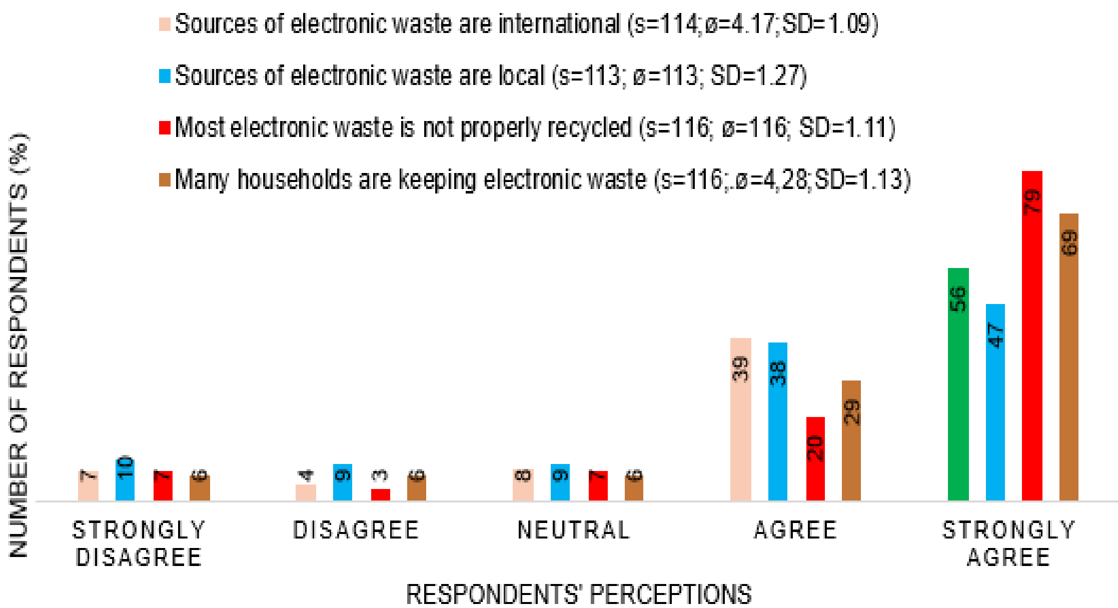
Some respondents believed that many urban households are keeping e-waste in their backyards in Harare, Zimbabwe. This implicitly confirmed Harare City Council's inability to put e-waste management systems in place. The cross-tabulation between ownership of electronic gadgets and dominance of e-waste in urban areas shows that there is a correlation between the two. The cross-tabulation results are shown below in Table 4.3 in the appendices.

The chi-square results show that there is a strong relationship of over 80% between ownership of electronic gadgets and dominance of e-waste. These results confirm the hypothesis that there is a link between population size and electronic waste generated. Thus, the bigger the population, the more the e-waste it generates. It points to an adamant population who might pay a deaf ear and a blind eye towards the management of e-waste as evidenced by multiple illegal e-waste dumps across Harare, Zimbabwe. This means that the management of e-waste requires that there be mechanisms in place to educate the population on e-waste as this is the most critical aspect of e-waste management.

Since there is more e-waste generated in urban areas, it is the collective responsibility of all stakeholders to coordinate and effectively manage e-waste. However, at present, it appears householders are not doing their part to manage e-waste. A total of ninety-six (96) respondents who were interviewed confirmed that urban householders are keeping e-waste in their backyards when these could be recycled. Furthermore, 92.2% of the respondents believed that recycling e-waste is not common in Harare. This is contrary to internationally conventional ways of the efficient waste management ladder which dictates that waste has to be separated and then recycled, reused and/or disposed of. Moreover, 87% of the respondents agreed with the view that most e-waste is not properly managed in Harare, Zimbabwe.

About 107 respondents indicated that e-waste is mixed with other forms of household solid waste and then disposed of, thus, a lot needs to be done to improve e-waste management in Harare, Zimbabwe. In support of the findings, the same was noted by Bogale, (2012), who indicated that developing countries without viable landfills and recycling facilities simply dump e-waste all over along with other forms of household solid waste. In fact, Mmereki, *et al.,* (2012) and Bogale, (2012), indicated that in developing countries like Botswana, solid waste management is becoming a daunting task including collection and disposal. According to Chirisa, (2012), Harare has seen the proliferation of illegal dumpsites on the streets. This complicates e-waste management as people are now dumping it anywhere, just like they do with other household solid waste. This is illustrated in Figure 4.2 below

Figure 4.2: Electronic Waste Sources




The respondents knew the sources of e-waste. Fifty-six (56) out of 114 respondents or 49.1 % of them strongly agreed that sources of electronic waste are international. Thirty-nine (39) or 34.2 % of them agreed. This means a total of ninety-five (95) or (83.3 %) respondents take the source of e-waste in Harare, Zimbabwe as international since the economic situation entails that Zimbabwe cannot produce many electrical goods because most industries have closed down. This could be interpreted as evidence that most respondents acknowledge that much of the electronic goods in Harare, Zimbabwe are imported from abroad. The source of the goods even before they become e-waste is being regarded as the source of the e-waste itself because some of the goods are imported second-hand and some as new products but, with a small life span. Most developing countries cannot deal with e-waste. Countries like Botswana, Zimbabwe, Mozambique, and Zambia are only consuming electronic goods. There is no database of the amount of e-waste being generated (UNDP, 2008). This mirrors a poor e-waste management system since it is difficult if not impossible to manage e-waste without proper statistics.

### 4.3 NATURE OF E-WASTES IN PARTS OF HARARE

This section highlights the nature of e-waste in Harare. Plate 4.1 presents e-waste in Harare at the Pomona dumpsite and close to the hovel where recyclers reside and pack their daily waste from. There are generally plastics from e-waste and this shows that most metal parts of this e-waste are the main targets. The e-waste is scattered all over the dumpsite and most of it close to the place where the people who scavenge for waste sort their daily finds. The people who reside at the dump and take recycling of waste for a living, stay in some shacks. From one location they sort not only e-waste, but also other forms of waste. This is the place where buyers come with their trucks to buy what they take as resources in their various recycling endeavours.  Some ferry the gathered waste to the market outside the residential areas of Mbare, Lusaka and others.

Plate 4.1: Electronic waste at Pomona dumpsite in Harare

Source: Field survey, (2019)

Plate 4.1 above shows different kinds of electronic waste. The findings indicate that e-waste includes obsolete electronics products such as radios, televisions, cell phones, electrical jugs, irons, fridges, remote controls, and other electrical or battery-powered appliances. The study findings also indicate that e-waste may be small electrical equipment which in most cases lead to increased rates of environmental pollution and health hazards. These findings can be said to be in line with the literature by Oteng-Ababio, (2012) who presents another unique way of classifying e-waste.

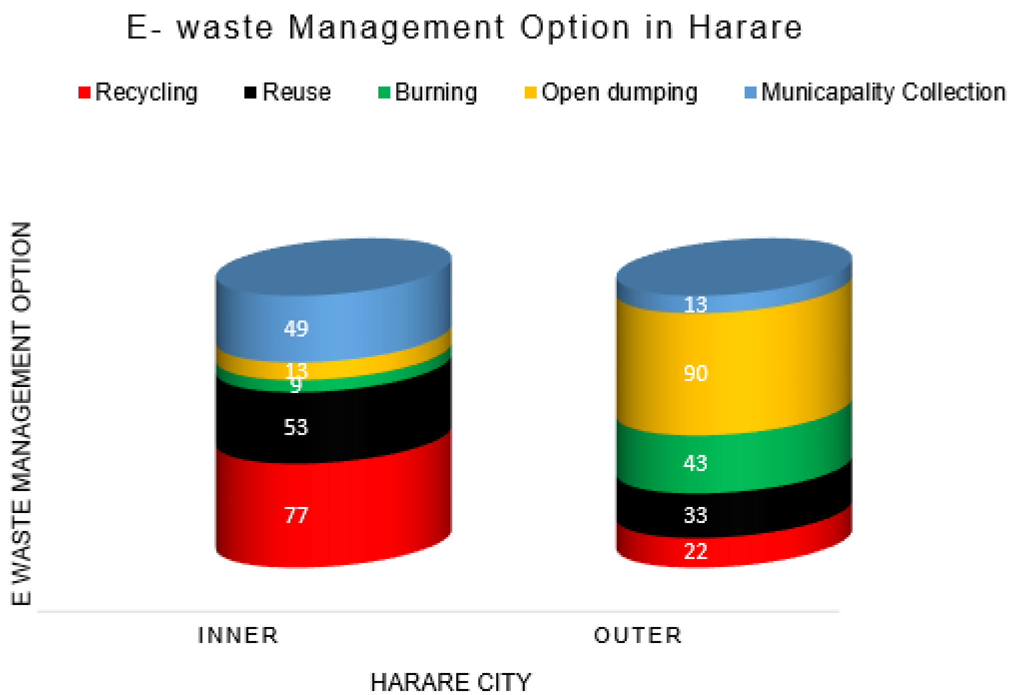
### 4.3.1 E-WASTE MANAGEMENT OPTIONS: INNER AND OUTER CITY HARARE

Despite the various causes of poor e-waste management in Harare, several options were identified as possible methods being employed to manage e-waste in the inner and outer city of Harare, Zimbabwe. These include residential areas where the majority of illegal dumpsites were observed. The identified options were presented in Figure 4.3 below. It must however be noted that these are what the general populace of Harare perceives to be properly used methods. Though these are not properly employed to

ensure effective e-waste management and, in some cases, unacceptable.

The data presented in Figure 4.3 below shows that people in the outer city and the residential areas throw their e-waste in open dumps close to their houses. This was shown by 90 participants out of 201 who indicated that there was indiscriminate dumping by most residents as a way of disposing of their e-waste. Dumping in the inner city seems almost non-existent. Only thirteen out of the 201 respondents indicated that they sometimes witness such e-waste close to Harare's main railway station on the periphery of the city. Burning of e-waste akin to what happens at the Pomona main dumpsite, is also common at roadside dumps in residential areas. Conversely, burning in the inner-city is limited and only common at the periphery of the city where street people reside and sometimes burn anything for warmth, especially during cold winter nights.

Figure 4.3: E-Waste Management Options in the Inner and Outer City of Harare




Sources: Primary Data, (2019)

Other management strategies attracted very little attention, yet they are the most critical. These included recycling and reusing, as well as municipality collection. That as it may be, the inner-city showed that all the identified burning, scavenging and dumping aspects found there was at a very limited level. Recycling and reusing accounted for 77 and 53 respectively out of 201. This is common where there is the repair of faulty radios, televisions, cell phones and other electronic goods. At such inner-city places, faulty goods are returned to the sellers for repair, dismantling and fixing for customers. Given this, the management of e-waste in the inner city is not as poor as in residential areas where the majority of the people reside and little if any municipal collection is done. As such, the management of e-waste in the inner city is relatively better, because individuals who do not throw away their old electrical goods take them for repairs.

Conversely, in the residential areas, residents at times simply throw the old electrical goods away. Thus, the people resort to rudimentary e-waste management options like burning. It is perhaps because of this unavailability of e-waste management structures and systems that a lot of obsolete computers and other electronic goods continue to be kept in government offices are still yet to be disposed of. One can equally surmise that quite a lot of e-waste remains stored within the city's buildings. If this is indeed so, the management of electronic waste requires urgent attention as, without it, the potential for serious pollution remains, especially when the stored e-waste is finally disposed of into mainstream waste. There is therefore an urgent need for a policy on e-waste which will compel all the city's residents to recycle at designated areas, as well as for the government to dispose of obsolete electrical goods in an environmentally proper manner.

The notion that e-waste is not properly recycled in Harare, Zimbabwe was fortified by seventy-nine (79) out of 116 respondents or 68.1 % who strongly agreed that there is no proper recycling of e-waste in the city. Twenty (20) or 17.2 % agreed with the statement. This gives a combined total of 85.3 % of respondents who agreed that e-waste is not being properly recycled in Harare, Zimbabwe. A combined minority of 10 respondents or 7.6 % disagreed and strongly disagreed that e-waste was not properly recycled. This concurs with Makwara and Magudu (2013), who lamented that the lack of separation of household solid waste results in the birth of an assortment of domestic solid waste that results in e-waste being dumped on dumpsites that are not properly constructed. The result of which is that it seeps into underground water where it contaminates it.

The respondents also felt that many households are keeping e-waste. Sixty-nine (69) out of 116 or 59.4 % strongly agreed and twenty-nine (29) respondents or 25 % agreed that many households are keeping e-waste. The two categories that at least agreed that many households are keeping e-waste makeup 88.4 % of the respondents. The keeping of electronic waste could mean that even when the gadgets are no longer working the households keep them and do not want to discard them. Electrical and electronic goods are usually stored for a while for perceived value (physical or emotional) before disposal. The e-waste could be the old black and white televisions (TV) that were replaced by a colour TV; the old radios that used to play vinyl records; wiz-tech decoders, it could be the early type of cell phones that were introduced in Zimbabwe in the late 1990s which are still being kept. There is a possibility that some old electronic goods are being kept as souvenirs as households sometimes use these to jog their memories and enjoy nostalgic moments. However, these are being branded as e-waste by the majority of the respondents.

One of the strategies used to manage e-waste in Harare is the use of informal waste scavengers who salvage electrical and electronic products for recycling. Research findings indicate that recycling of e-waste is generally done at a very small scale in Harare and this is done by unemployed people who pick items from the dumpsites for reselling. The City of Harare issued 300 recycling licenses to individuals and individual companies (Mandevere 2016) and none of these licences are specifically for e-waste. This demonstrates how e-waste in Harare is regarded as any other form of solid waste, despite the heavy metals it carries. Plate 4.2 below shows some of the informal recyclers or e-waste scavengers with their wares.

Plate 4-2: Individuals collecting recyclable materials at Pomona Dumpsite

Sources: Field survey, (2019).

According to Terazono, *et al.,* (2006) employment of local people, local economic growth, and a profitable business may be generated, especially for the informal sector in e-waste management. The researcher interviewed pickers of waste at Pomona to understand what their business involves. The first interviewee has been picking waste that can be recycled and has been doing it for three years. His process is as follows: he collects the waste; cleans the waste; breaks the waste into usable chunks; and then separates the important items from the useless materials. Thereafter, important pickings are grouped according to potential markets. He disclosed that he is unaware of the side effects on his health that can be attributed to the waste dumped at the dumpsite. It is however critical to note that there are risks around the dismantling of e-waste especially with the use of fire. He pays ZWL$5 to the municipality per month for collecting recyclables from the dumpsite. These findings are supported by Terazono, *et al.,* (2006), who posits that in many developing countries, the informal sector play a significant role in recycling e-waste.

Although some people suggest that these informal activities should not necessarily be formalized, in Harare they have been critical in helping reduce the scourge of e-waste. E-waste imposes many challenges on the recycling industry (Smith, Sonnenfeld and Naguib Pellow, 2006), because it contains many different materials that are mixed, bolted, screwed, snapped, glued or soldered together. Toxic materials are attached to non-toxic materials, which makes separation of materials for reclamation difficult, hence the crude and primitive methods employed by the scavengers to recycle e-waste.

It was found that the residents of Harare sometimes resort to burning waste as a management option. Interviews with authorities indicated that the cause of this is the failure of the municipality to collect waste from the residential areas. Unfortunately, the open burning of e-waste can emit carbon monoxide that could be poisonous to the blood when inhaled. The residuals produced when blown by the wind and inhaled can lead to severe respiratory infections for the people residing in areas close to areas where such burning would have taken place. One respondent reported that there are more than five burning points in most of Harare's high-density residential areas. The likelihood of ongoing e-waste pollution consequent to burning is therefore very high in Harare, Zimbabwe.

It must however be noted that not all e-waste is burnt. Some are collected and resold without being burnt as shown on Plate 4.3 below, where some e-waste is heaped for possible selling to interested recyclers.

Plate 4-3: E-waste picked and set aside for reselling

Source: Field Survey, (2019).

Plate 4.3 above shows electronic waste items at the Pomona dumpsite. The recyclers have picked them and are ready for reselling. The pickers in some cases do not dismantle this e-waste. They instead sell them to other people who will then dismantle them and get critical components for reselling or use in other similar gadgets that will be requiring new parts. The market for such electronic waste picked from the dumpsite is common in areas like Mbare, Magaba, Siyaso and the main market areas like Machipisa, Gazaland and other areas. There, the general public can visit and buy items that they would have failed to buy in the main market as new products or parts because they are unaffordable. Below Plate 4.4 is a picture of various remote controls collected and are being sold in Mbare Musika of Harare.

Plate 4-4: Second-hand remote controls on the market

Source: Field Survey, (2019).

This shows that e-waste products find their way to the market for reselling. The concept of holding on to e-waste cannot be ruled out as there is a general perception that there are people who can still buy these remote controls for use, irrespective of the age and model. Consequently, certain old outdated electrical and electronic goods are still kept indoors for various reasons.

It must however be noted that there is minimal e-waste reusing and recycling in Harare as most of the e-waste is still kept for perceived benefits. Recycling of e-waste is generally done at a very small scale in Harare by unemployed people who pick items from the dumpsites for reselling.

According to Mandevere, (2016), the City of Harare has issued 300 recycling licenses to individuals and individual companies - none of these licences is specifically for e-waste recycling. However, the fly in the ointment is that heavy metal pollution results from the inhalation, ingestion and dermal intake of particulate matter from primitive e-waste recycling sites, expose humans to dioxins and furans. One of the heavy metals from e-waste is cadmium. Cadmium is very toxic, all soils and rocks including mineral fertilizers contain some cadmium. It has many uses, for example, metal coatings, batteries and extensively used electroplating. Cadmium exposure can cause cadmium pneumonitis, bone defects such as osteocalcin and osteoporosis (Verma and Dwivedi, 2013). All these are serious health problems could result if e-waste management is not dealt with in Harare, Zimbabwe, and may cause human health problems to those who do the picking and recycling of e-waste using rudimental and primitive means.

## 4.4 CHAPTER SUMMARY

The findings indicate that Harare uses different e-waste management practices, such as informal re-cycling, and dumping at dumpsite namely Pomona and the Golden Quarry. However, these strategies are inadequate to deal with the rate at which the scourge of e-waste is spreading. The problem of e-waste keeps on growing and this is a sure sign that these strategies are inadequate. The next chapter examines the existing environmental laws concerning electronic waste management in Zimbabwe.

# Chapter 5

## E-WASTE MANAGEMENT ENVIRONMENTAL LAWS IN ZIMBABWE

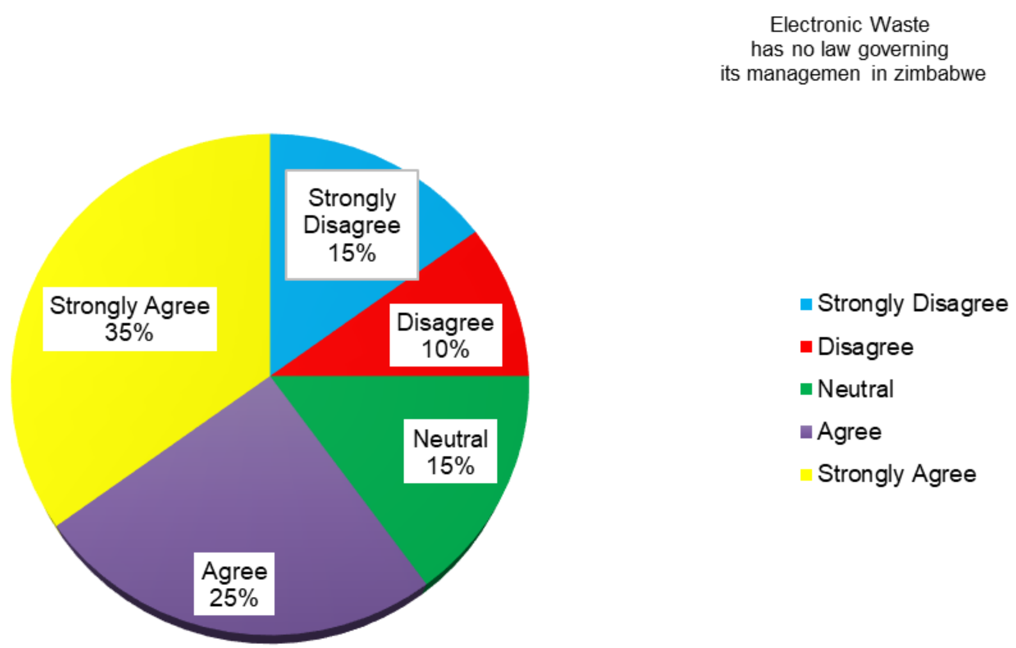
### 5.0 INTRODUCTION

The preceding chapter assessed electronic waste (e-waste) management strategies current in Harare. This chapter reviews the existing environmental laws about electronic waste management in Zimbabwe by examining those in existence with e-waste, its disposal and recycling in Harare.

### 5.1 EXAMINING EXISTING ENVIRONMENTAL LAWS ABOUT E-WASTE

Outdated and poorly enforced environmental legislation that has no set standards has complicated waste management in Sub-Saharan Africa (SSA) (Achankeng, 2003). Study findings indicate that e-waste has become a major problem in Harare, Zimbabwe posing both environmental and health problems. This is acknowledged by Tevera, *et al.,* (2002), who suggested that a lapse in the management of waste in Zimbabwe is a product of poor legislative implementation. Study findings after a question on e-waste legislation to authorities indicate that Zimbabwe generally has no policy or legislation on e-waste. While the Environmental Management Act Chapter 20:27 prohibits the discharge of hazardous substance into the environment, there is no specific legislation regulating e-waste. Therefore, one may inevitably conclude that Zimbabwe’s current waste management laws are inadequate to address the ongoing e-waste management problems. This is even though the Zimbabwean Constitution gives the right to a clean environment to all. Figure 5.1 below shows how respondents reacted to the notion that electronic waste has no law governing its management in Zimbabwe. It is critical to note that management of e-waste should be directed by law, legislation without which it's impossible to do proper e-waste management. To check on the law on e-waste several questions were asked. Figure 5.1 presents how some participants reacted to questions regarding e-waste management law in Harare, Zimbabwe.

Figure 5.1: E-Waste Legislation in Zimbabwe




Sources: Primary Data, (2019).

Sixty percent of the respondents believed that there are enough legislative pieces that govern e-waste management. This is probably because the public knows of the Environmental Management Act, the Water Act, Public Health Act and the Forestry Act and assume that one or more of these acts deals with e-waste management. Unfortunately, none of these acts mentions e-waste and its management. Only the EMA act talks of hazardous substance, but with minimal if any focus on e-waste. An official from ZEMA reported that there is no policy or law on e-waste; though plans are underway to come up with a legal instrument on e-waste. So, despite the majority of respondents indicating that there is enough legislation dealing with e-waste, a closer look at the existing laws shows this not to be so. There seems to be a mix-up between knowing the existing environmental laws and their contents, as well as what they entail regarding e-waste management.  The available legislation like the Water Act 1996, Public Health Act 1924, Urban Council Act 1995 and the Regional and Town planning

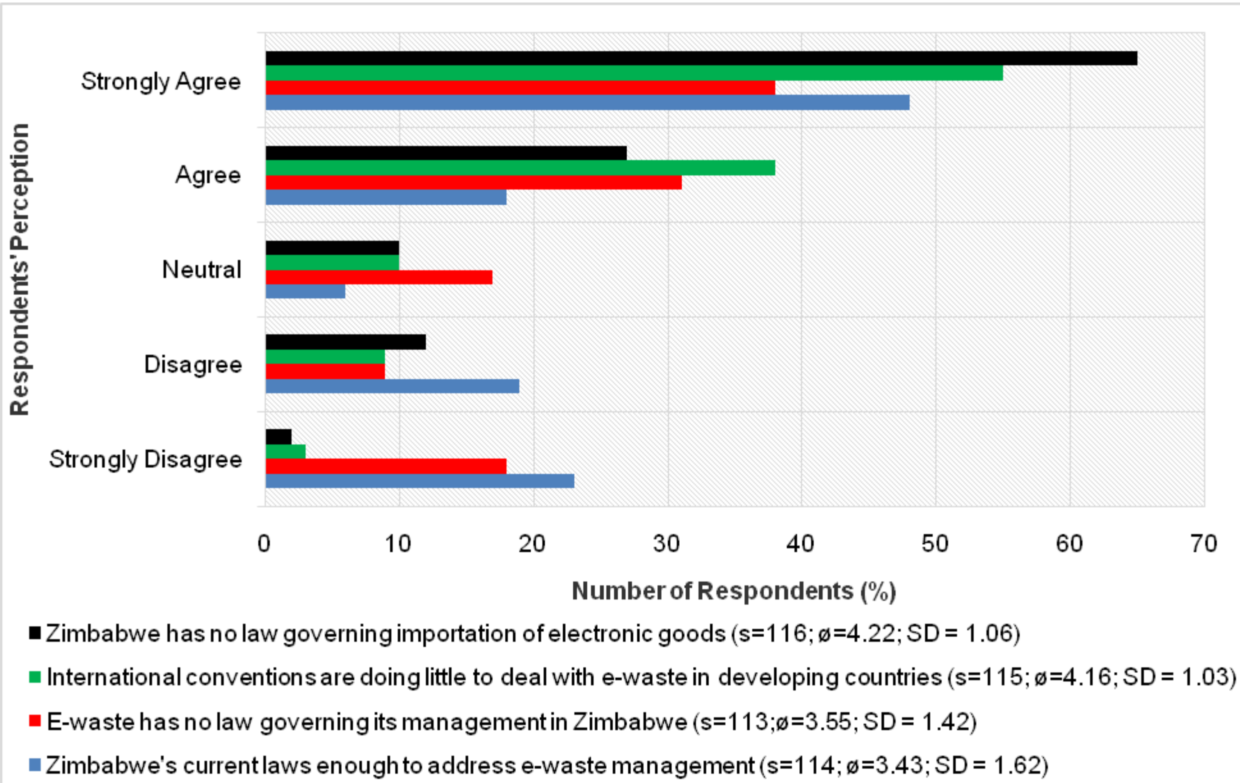
Act 1988, does not mention e-waste. Maybe this is because it was enacted before the electronic revolution or when it was just beginning as in the case of EMA of 2002. This means a lot still needs to be done to improve public awareness regarding e-waste, as some confuse it with other forms of waste.

The respondents also believed that international conventions on e-waste management are doing very little to effect change in developing countries and cities like Harare. This is because it is from these conventions that individual countries adopt legislation on e-waste management for incorporation into their laws. It is believed that about 60% of the world's population lives in countries with e-waste legislation (Balde *et al.,* 2016). Be that as it may, however, it is regrettable that most of these are in developed countries and only 41 of them collect international statistics on e-waste (Balde *et al.,* 2017). This makes it difficult to quantify the amount of e-waste to be dealt with across the globe by individual countries and most importantly Harare, Zimbabwe, one of the countries with no statistics on e-waste. The importance of keeping statistical data cannot be over-emphasized as new legislation is often based on statistics of the amount of waste generated. As such, since Zimbabwe is not collecting such statistics, the authorities are oblivious of the threat e-waste poses and unprepared to start work on e-waste legislation.

Figure 5.2 below indicates the responses given on whether Zimbabwe's environmental laws are adequate to deal with the growing problem of e-waste in Harare and Zimbabwe in general. From the information presented (Figure 5.2) below, forty-eight (48) or 42.1 % strongly agreed that Zimbabwe has environmental laws adequate to address the management issues about e-waste whilst eighteen (18) or 15.8 % agreed with the statement. This gives a combined total of 57.9 % who agree that the environmental laws are adequate.

Those who strongly disagreed with the adequacy of environmental laws are twenty-three (23) out of 114 (20.2%) of the respondents to the question. The number disagreeing was (19) nineteen (16.7 %). An excel sheet showed that a combined total of those respondents in disagreement with the assertion that Zimbabwe's laws are adequate for the management of e-waste was therefore 36.9 %. This is indicated by an SD =1.62, where the responses are spread out to both extremes on the values of the options. Only six (6) respondents or 5.3 % were unsure about the adequacy of Zimbabwe's environmental laws.

Figure 5.2: Perceptions on the adequacy of Zimbabwe's Environmental Laws




Sources: Primary Data, (2019).

The interview with the Environmental Management Authority of Zimbabwe (EMA) revealed that the current Environmental Law and Auxiliary Instruments are adequate for the management of e-waste in the country. The Statutory Instrument (SI) 12 of 2012 is functional and requires all local authorities to have hazardous waste landfills in their areas of jurisdiction. It must however be noted that Harare as the capital city does not have such a landfill let alone other urban areas in Zimbabwe. The authorities interviewed from EMA also disclosed that the local municipalities have claimed that they have no land available for landfills. They did not give a government position regarding this since ZEMA as an Authority is in no position to help because they are only a regulatory body constituted under Zimbabwean law. One area in the regulations that EMA views as a setback is that there is no control on the importation of electrical and electronic goods in Zimbabwe. The question to ask would be whether industries and traders import e-waste? There could be different perceptions on what to consider as e-waste. The reference to importation of e-waste might have been a reference to the importation of second-hand gadgets that no longer have a long life or some goods that are not necessarily second-hand but are of poor quality lacking in durability and robustness. Such products are short-lived and once used, quickly turn to e-waste. The broad category for such imports could be taken as importing e-waste. These findings are supported by Oteng-Ababio, (2012) who indicated that sending old electronic equipment to developing countries is often hailed as “bridging the digital divide”, but all too often this simply means dumping useless equipment on the poor.

One estimate suggests that 25 – 75 % of second-hand goods imported to Africa cannot be reused Oteng-Ababio, (2012). People in the developed countries bring electronic equipment here ostensibly to bridge the digital gap, but they are creating a digital dump (United Nations Environmental Management Group, 2017). Terazono, *et al.,* (2006) indicated that it is difficult to accurately and consistently identify the amounts of second-hand electronic products because most national systems tracking trade do not have specific codes distinguishing new and second-hand goods under the Harmonized Commodity Description and Coding System (HS).

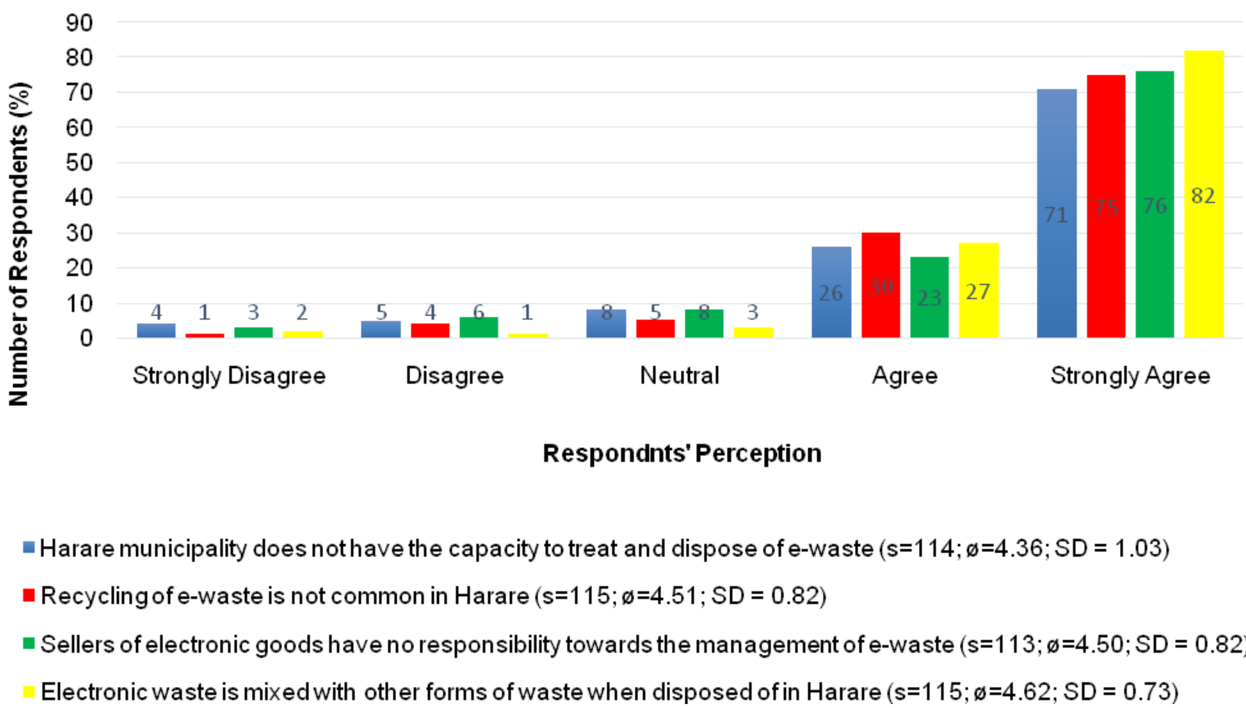
Irrespective of the various environmental legislative documents, the Ministry of Environment and Tourism, (2004) lamented that Zimbabwe does not have an overall waste management policy and this has a contributory factor to the crisis in the waste management sector in most of her urban centres (Makuku and Masiye, 2010). Senkoro, (2003) and Kidd, (2009) Tevera *et al.,* (2002) also agreed with the point that ineffective enforcement of these instruments leads to environmental and health problems.

In a nutshell, the Zimbabwean laws handling waste management and in particular e-waste are not linear, they are rather a diverse aspect whose involvement is multiple with diverse and divergent views and objectives. This makes e-waste management complex as a lot has to be done to ensure a common law of e-waste which is an across-the-board kind of law involving collaboration among government ministries and department, NGOs, formal and informal players in the field of e-waste management and which drinks from the cup of international conventions.

## 5.2 DISPOSAL AND RECYCLING OF E-WASTE IN HARARE

The study assessed the various measures taken to dispose and recycle e-waste in Harare. The respondents to the questionnaires provided their choices to various statements concerning the disposal and recycling of e-waste in the Harare municipality as shown in Figure 5.3.

Figure 5.3: Disposing and Recycling of E-waste




Sources: Primary Data, (2019).

Seventy-one out of 114 (62,3%) respondents who provided answers on whether Harare Municipality could treat and dispose of e-waste strongly agreed with the assertion that the city of Harare cannot recycle, treat and dispose of e-waste. Twenty-six (26) or 22.8 % were also in agreement with this assertion. This shows a general picture of poor e-waste management in the city of Harare. Thus, one may conclude that the City of Harare is experiencing e-waste challenges because the available e-waste management mechanisms such as scavenging and recycling of e-waste are considered inadequate by the majority of respondents. Such high levels of pollution are hazardous not only to human health but also to the environment. According to ZINWA, there are 15 000 boreholes in Harare and 4 000 of which are unregistered. These are at risk of pollution from heavy metals. The same applies to Lake Chivero, the main water source for Harare, that residents and authorities have already dubbed a polluted lake. In the same vein, the Mottern Jefry Water Works is struggling to provide clean water for Harare. This exposes the residents of Harare to heavy metals related illnesses.

The assertion that Harare lacks adequate mechanisms such as technology to handle e-waste also found support in EMA. Interviews with EMA indicated that in Harare, e-waste is dumped at Pomona dumpsite except for dangerous substances which are dumped at the Golden Quarry Dumpsite. Interestingly, e-waste is not treated as dangerous in this regard and is dumped at the non-hazardous official dumpsite along with other waste forms. Observations proved this as evidence showed that battery waste and other e-waste are being dumped at Pomona, a non-hazardous dumpsite. This means there is indeed poor e-waste management in Harare. The general position of ZEMA is that although the government has passed enough legislation on the environment since the Zimbabwe Environmental Management Act and other statutory instruments on waste management are already in use, the central government has not availed land and other resources for proper landfills. EMA disclosed that the construction of e-waste landfills is an expensive task for local authorities like the City of Harare to undertake. With the economic challenges that Zimbabwe is experiencing the problem is compounded since there are no external investors to fund such projects.

Only four (4) of the respondents strongly disagreed and five (5) disagreed with the statement that Harare cannot treat and dispose of e-waste. Those in disagreement constituted 7.9 % of responses to the statement that the municipality of Harare could not recycle and dispose of e-waste. This may be due to a lack of awareness as some respondents may see the undesignated dumping sites sprouting up everywhere in the city as acceptable. Such voices are dismissed by UNEP, (2013) which indicated that open and often undesignated dumping remains the prevalent waste disposal method in most low-income countries like Zimbabwe and their cities.

The study also sought to understand whether recycling of e-waste is common in Harare. Seventy-five (75) respondents or 65.2 % strongly agree that recycling of e-waste is not common in Harare. Thirty (30) or 26.1 % of the respondents agree as well, thus giving a 91.3 % total of participants agreeing overall that recycling is uncommon in Harare. This means there is little recycling of e-waste in Harare, Zimbabwe and this points to poor e-waste management since recycling is the most critical management tool for e-waste. This suggests that most e-waste in Harare, Zimbabwe is either illegally disposed of at official dumpsites or dumped at various dumps across the town, to pollute the environment. The unavailability of e-waste recycling amenities, contradicts the finding by Prakash and Manhart, (2010), that the e-waste recycling industry plays an important role in reducing the accumulation of global e-waste. The accumulation of e-waste in Harare, Zimbabwe is increasing as critical management options for e-waste are non-existent only scavenging seems the major player.

The study also sought to solicit answers on whether sellers of electrical and electronic products have or undertake responsibility towards e-waste management. Seventy-six (76) or 67.3 % of respondents strongly agreed to this while 23 or 20.4 % agree with the assertion that sellers of electrical and electronic products generally take no responsibility for the management of e-waste. The two responses add to 87.7 % of those who acknowledged that the sellers of electronic goods have no responsibility to the management of e-waste. If customers become informed about e-waste, sales of electrical and electronic products, particularly cheap electrical and electronic products commonly referred to as *Zhing Zhong or* made in China, as well as that of second-hand products could decline. This shows that while individuals and entities are trying to deal with the problem of e-waste, there is a section of society that sees it as detrimental to their profit margin. Consequently, they are antagonistic to environmental education on proper e-waste management.

The sellers are just retailers and not manufacturers, and by selling they are satisfying a need just like the sellers of groceries. In developed countries, the manufacturers take back products after their life span, for safe destruction and, or, recovery of important materials (Kuper and Hojsik, 2008 and Oteng-Ababio, 2012). According to Sitaramaiah, *et al.,* (2014), Nokia and Samsung have a take-back scheme in the European Union, Australia and parts of Latin America. This offer is, however, unavailable for Africa and more so the foreign producers do not have any relationship with local sellers to take back and manage e-waste.

The study also sought to understand how e-waste and other forms of waste are handled by e-waste management authorities in cities in developing countries. The majority of respondents (94.8%) highlighted that e-waste is mixed with other forms of waste when being disposed of by the Municipality of Harare. Three (3) respondents were not sure, while a total of 3 disagreed. However, observation conducted by the researcher proves beyond doubt that e-waste indeed is mixed with other types of waste. The dumpsites in Harare, are business opportunities for people who forage for different materials like plastics, metals and copper from electronic circuits for re-sale to factories some of which are based in South Africa, who recycle e-waste converting them into raw materials. It must however be noted clearly that this kind of waste management is nothing but poor as waste separation is critical in waste management in general. Plate 5.1 below highlights some of the e-waste and metals sought by informal recyclers for re-sale.

Plate 5.1 below shows electronic waste items that the Pomona dumpsite scavengers had picked and were ready for sale. As alluded to earlier, the pickers in some cases do not dismantle all e-waste. Instead, they sell them to other people who then dismantle them and get still usable components for reseller re-use in similar gadgets requiring repair. Interviews with informal e-waste workers also showed that they do not only pick such products at the official dumpsite alone, they obtain them wherever they are dumped. This shows that the city's by-laws are ineffective in ensuring that e-waste or other forms of waste are properly disposed of.

Illegal dumping is not a product of a single cause. Rather, it is a combination of complex and interactive factors which act simultaneously. Despite evidence of illegal dumping, there are no known cases of people who have been taken to courts for illegal dumping. There is no environmental court in Harare, Zimbabwe. Instead, anything concerning environmental pollution is dealt with in the general courts which often lack depth on environmental issues.

Plate 5-1: E-Waste picked and other metals ready for re-selling

Source: Field Survey, (2019).

This shows that most waste management in Harare is being spearheaded by the informal sector. There are no known official e-waste recyclers. The interviews with both EMA and city authorities also testified to the fact that e-waste management in Harare is currently being done by dumpsite searchers and pickers who search and pick both discarded waste and e-waste for personal use, reselling and, at times, recycling. In the face of Harare's limited e-waste management, such e-waste administration is unreliable.

## 5.3 CHAPTER SUMMARY

Despite several pieces of legislation, environmental law in Zimbabwe is inadequate to deal with e-waste management. The regulatory framework on e-waste management is not available and the one being used lacks set standards and as a result, has been complicating e-waste management efforts. In Zimbabwe, there is a general reluctance by all government departments and agencies to prosecute offenders in waste management issues. It is also important to have an inventory of e-waste in Harare as this will give a clear picture of e-waste giving direction on policy formulation as currently e-waste issues are based on anecdotal data and evidence, with no inventories on e-waste. The next chapter focuses on the establishment of the effectiveness of available electronic waste management strategies being used in Harare.

# Chapter 6

## THE IMPACT OF POOR E-WASTE MANAGEMENT - HEAVY METAL CONCENTRATION IN SOILS AND WATER SAMPLES

### 6.0 INTRODUCTION

The preceding chapter examined the existing environmental laws concerning electronic waste management in Harare, Zimbabwe. This chapter assesses the effectiveness of e-waste management strategies being used in Harare. This was done through undertaking soil and water tests in various location and assessing the nature, levels, extent and distribution of e-waste related pollution. Specifically, this chapter focuses on soil and water sampling and analysis in Harare to check for the presence and levels of heavy metal concentration in the water and soils in Harare. The various heavy metals were tested against international, regional and local allowable limits.

### 6.1 SOIL AND WATER SAMPLING POINTS IN HARARE

Soil and water samples were taken from various locations around Harare. Their coordinates were recorded to enable geographical and pictorial access to the areas where samples were taken. Also, the co-ordinates provide information about heavy metal concentration, factors contributing to heavy metals in both soil and water, insight into the management of other forms of waste, other than e-waste in the given locations, which are capable of decomposing into heavy metals and polluting the environment thereby threatening public health. Table 6.1 below shows the coordinates of the various points from which samples of both water and soils were taken. The samples totalled 33 and 15 soil and water samples, respectively. Since the sampling areas varied, the results of the laboratory tests are also heterogeneous. This indicated, that some areas are heavily contaminated while the other sampled areas are not.

## Table 6-1: Soil and Water Sampling Co-ordinates

**Legend:** SSN = Soil Sample Number, PCD = Position Coordinates, GD = General Description, WSN = Water Sample Number

| SSN | PCD | GD | SSN | PCD | GD |
|---|---|---|---|---|---|
| **1** | S 17 °46’49.788<br>E 30°58’09.041 | Bluffhill area roadside waste disposal site. Evidence of electronic waste | 26 | S 17° 43’44.501<br>E 31° 04’44.909 | Dumpsite Pomona |
| **2** | S 17° 84’51.990<br>E 30° 59’14.730 | Golden Quarry Dumpsite edges | 27 | S 17° 43’44.849<br>E 31° 04’43.740 | Dumpsite Pomona |
| **3** | S 17° 48’49.697<br>E 30° 59’11.718 | Golden Quarry Dumpsite water hole | 28 | S 17° 43’47.742<br>E 31° 04’38.899 | Dumpsite Pomona |
| **4** | S 17° 48’48.012<br>E 30° 59’11.778 | Golden Quarry swampy area | 29 | S 17° 44’16.151<br>E 31° 05’02.100 | Pond close to the army signal point to the east |
| **5** | S 17° 54’40.751<br>E 30° 59’23.249 | Mukuvisi river closer to Glen Norah C extension | 30 | S 17° 43’51.708<br>E 31° 04’44.710 | Out of the dump to the south |
| **6** | S 17° 54’41.940<br>E 30° 59’22.367 | Mukuvisi area in Glen Norah C extension | 31 | S 17° 43’47.280<br>E 31° 04’32.959 | Middle of the dump |
| **7** | S 17° 54’22.848<br>E 31° 02’16.369 | Waterfalls | 32 | S 17° 43’56.801<br>E 31° 04’26.440 | Close to the monitoring pond |
| **8** | S 17° 50’56.897<br>E 31° 06’40.450 | Masasa just outside the Mukuvisi River | 33 | S 17° 47’19.398<br>S 31° 04’07.800 | Control at Borrowdale road |
| **9** | S 17° 50’55.848<br>E 31° 06’40.180 | Masasa just outside the Mukuvisi River | | | |
| **10** | S 17° 50’50.489<br>E 31° 00’53.759 | Omer road | **WSN** | **PCD** | **GD** |
| **11** | S 17° 52’44.172<br>E 30° 59’39.240 | Willovale road Highfield | 1 | S 17° 46’48.528<br>E 30° 58’09.419 | Bluff hill area close to a swampy point |
| **12** | S 17° 52’45.161<br>E 30° 59’37.097 | Willvale Flats | 2 | S 17° 48’49.697<br>E 30° 59’11.718 | Golden Quarry Dumpsite water hole |
| **13** | S 17° 52’53.388<br>E 30° 59’03.797 | New Flat Willovale road | 3 | S 17° 50’36.491<br>E 30° 58’46.590 | Mukuvisi River Belvedere West Warren Park Moomba area and Kambuzuma as well as Westwood |
| **14** | S 17° 53’06.191<br>E 30° 58’44.088 | Willovale road along Willovale road | 4 | S 17° 54’43.320<br>E 30° 59’23.352 | Mukuvisi River flowing water in Glen Norah C Extension closer to Mbudzi roundabout |
| **15** | S 17° 53’09.618<br>E 30° 58’37.980 | Willovale road along Willovale road | 5 [control] | S 17° 54’20.058<br>E 31° 03’12.660 | In waterfalls at a public water borehole and become a control |
| **16** | S 17° 53’11.621<br>E 30° 58’34.901 | Willovale road along Willovale road | 6 | S 17° 53’47.550<br>E 31° 02’22.660 | Waterfalls Retreat Farm |
| **17** | S 17° 53’30.600<br>E 30° 58’01.949 | Willovale road along Willovale road - | 7 | S 17° 52’21.119<br>E 31° 05’42.619 | Hatfield CNR 20 dales and St Patricks’ |
| **18** | S 17° 53’43.829<br>E 30° 59’47.099 | Highfield Mangwende Drive East of Harare | 8 | S 17° 50’57.300<br>E 31° 06’41.089 | Masasa Mukuvisi |
| **19** | S 17° 43’33.198<br>E 31° 04’14.260 | Pomona dumpsite outside to the North close to the Golf course | 9 | S 17° 50’50.489<br>E 31° 00’53.759 | Coventry Road |
| **20** | S 17° 43’33.198<br>E 31° 0’41.4260 | Outer but closer to the dump Alps Road | 10 | S 17° 53’18.809<br>E 31° 00’14.849 | Omer Road industries |
| **21** | S 17° 43’33.198<br>E 31° 0’41.4260 | North of the dump dominated by plastics | 11 | S 17° 43’44.399<br>E 31° 04’44.839 | Leaches from a roadside in the dumpsite at Pomona |
| **22** | S 17° 43’39.540<br>E 31° 0’41.4260 | Inner dump, Pomona | 12 | S 17° 43’44.501<br>E 31° 04’44.839 | Leaches from a roadside in the dumpsite at Pomona |
| **23** | S 17° 43’39.071<br>E 31° 0’41.4260 | Dumpsite Pomona | 13 | S 17° 43’47.357<br>E 31° 04’44.230 | Water from a monitoring pond at Pomona to the East. |
| **24** | S 17° 43’40.422<br>E 31° 0’41.4260 | Dumpsite Pomona | 14 | S 17° 43’57.029<br>E 31° 04’26.509 | Water from a monitoring pond at Pomona to the South |
| **25** | S 17° 43’40.427<br>E 31° 04’44.760 | Dumpsite Pomona - | 15 | S 17° 44’00.612<br>E 31° 04’16.369 | Pomona borehole water |

Source: Field Survey, (2019).

It is widely accepted that heavy metal contaminants in sediments, soils and groundwater are one of the biggest threats to environmental and human health (Raulinaitis *et al.,* 2012). Although metals and metal compounds are natural constituents of all ecosystems that move between the atmosphere, hydrosphere and biosphere, (Bargagli, 2000) they are considered serious pollutants. However, it is not only their persistence and non-degradability in the environment that makes them harmful, their toxic effects on living organisms make them more so. When these metals and metal compounds exceed concentration levels given by organisations such as the World Health Organisation (WHO), Standard Association of Zimbabwe (SAZ), ZEMA and others, they become toxic.

To come up with an in-depth assessment, various sample issues were investigated. One of these was to access the leachate concentration for toxic heavy metals around selected major dumpsites, roadside dumps, rivers, streams, boreholes and shallow wells in randomly selected localities of Harare. A total of 15 samples of water were collected and analysed for lead, arsenic, mercury, cobalt, cadmium, zinc, nickel, iron, copper and manganese.

Similarly, 33 soil samples were collected and analysed for the same heavy metals using standard validated methods. The findings indicate varied results from the tests. Generally, however, the results indicated that some soils and water samples were both within, and outside permissible limits for heavy metals concentration set locally and internationally by such bodies as the: Standards Association of Zimbabwe (SAZ), ZEMA and the World Health Organization (WHO).

Soils sample were taken from various sites across Harare and the sites coordinates were captured in Table 6.1 above. Any analysis is of no value if the samples are not properly collected and stored. The time between sampling and analysis was kept minimum. Samples collected into pre-cleaned polyethylene bags. An auger and a shovel were used, the shovel was used to scoop sediments in the top 10 cm depth. The soil was first dug to loosen it up and pave way for an auger. The samples were stored in well labelled bags. Below is one such a site from which soil samples were collected.

The various sampling coordinates were the used to produce various maps that are presented in chapter 6 to show areas and concentration of heavy metals in Harare.

Plate 6-1: Sampling Point


Source: Field Survey, (2019).

The Plate 6.1 shows part of the sample points which were collected for analysis, the position is sample number 23 and its coordinates are: S 17° 43'39.071 / E 31° 0'41.4260. The samples were collected randomly and stochastically across the area of the various dumpsites and submitted to EMAL for analysis, mainly Arsenic (As), Cadmium (Cd), Cobalt (Co), Iron (Fe), Lead (Pb), Mercury (Hg) and Zinc (Zn).

## 6.2 ANALYSIS OF WATER SAMPLES FOR METALS

The results obtained for the analysis of water samples were tabulated as shown below in Table 6.2 and are varied in nature. Some are below the generally accepted limits, while others are slightly above the limit, others are way above acceptable levels.

Table 6.2 below shows the heavy metal distribution for all the water samples collected at the 15 sampling stations. Sampling station eight (8) had the highest concentration of Iron (63.00 mg/L) and Manganese (2.80 mg/L). Station fifteen (15) had Manganese concentration levels of >2.00 mg/L. Statutory Instrument 6 of 2007: Environmental Management (Effluent & Solid Waste Disposal) regulations outline allowable limits for Iron, Manganese and Lead as 1.0, 0.1 & 0.05 mg/L, respectively. Drinking water standards for Zimbabwe as documented in the SAZS 560:1997 show maximum allowable Iron, Manganese and Lead limits in drinking water of 1.0, 1.0 and 0.1 mg/L, respectively.

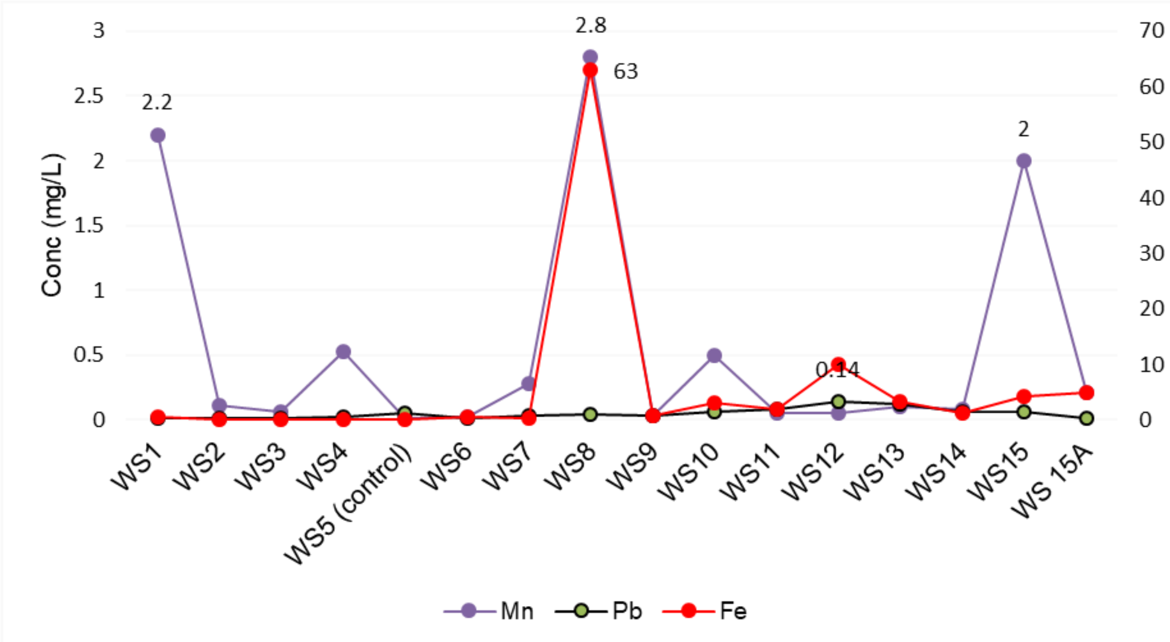
Table 6-2: Water Results for Heavy Metals

| **Lab Ref** | **Sample name** | **As** | **Cd** | **Co** | **Cu** | **Fe** | **Mn** | **Ni** | **Pb** | **Hg** | **Zn** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 186010 | Sample 1 | 0.025 | <0.01 | <0.01 | <0.01 | 0.48 | 2.20 | <0.01 | 0.01 | <0.01 | <0.01 |
| 186011 | Sample 2 | 0.50 | <0.01 | <0.01 | <0.01 | 0.05 | 0.11 | <0.01 | <0.01 | <0.01 | <0.01 |
| 186012 | Sample 3 | 0.50 | <0.01 | <0.01 | <0.01 | 0.11 | 0.06 | <0.01 | 0.01 | <0.01 | <0.01 |
| 186013 | Sample 4 | <0.01 | <0.01 | <0.01 | <0.01 | 0.13 | 0.53 | <0.01 | 0.02 | <0.01 | <0.01 |
| 186014 | Sample 5 | <0.01 | <0.01 | <0.01 | <0.01 | 0.03 | 0.01 | <0.01 | 0.05 | <0.01 | <0.01 |
| 186015 | Sample 6 | <0.01 | <0.01 | <0.01 | <0.01 | 0.53 | 0.02 | <0.01 | 0.01 | <0.01 | <0.01 |
| 186016 | Sample 7 | <0.01 | <0.01 | <0.01 | <0.01 | 0.38 | 0.28 | <0.01 | 0.03 | <0.01 | <0.01 |
| 186017 | Sample 8 | <0.01 | <0.01 | <0.01 | <0.01 | 63.00 | 2.80 | <0.01 | 0.04 | <0.01 | <0.01 |
| 186071 | Sample 9 | <0.01 | <0.01 | <0.01 | <0.01 | 0.80 | 0.03 | <0.01 | 0.03 | <0.01 | <0.01 |
| 186072 | Sample 10 | <0.01 | <0.01 | <0.01 | <0.01 | 3.14 | 0.50 | <0.01 | 0.06 | <0.01 | 0.02 |
| 186073 | Sample 11 | <0.01 | <0.01 | <0.01 | <0.01 | 1.89 | 0.05 | 0.09 | 0.08 | <0.01 | <0.01 |
| 186074 | Sample 12 | <0.01 | <0.01 | <0.01 | <0.01 | 9.90 | 0.05 | 0.09 | 0.14 | <0.01 | 0.04 |
| 186075 | Sample 13 | <0.01 | <0.01 | <0.01 | <0.01 | 3.38 | 0.10 | 0.03 | 0.12 | <0.01 | 0.02 |
| 186076 | Sample 14 | <0.01 | <0.01 | <0.01 | <0.01 | 1.12 | 0.08 | 0.12 | 0.06 | <0.01 | <0.01 |
| 186077 | Sample 15 | <0.01 | <0.01 | <0.01 | <0.01 | 4.20 | 2.00 | 0.03 | 0.06 | <0.01 | <0.01 |
| Guidelines' (WHO) | Maximum allowable limit | 10 μg / L | 0.005 mg / L | 0.05μg / L | 0.005 mg/L | 0.05mg /L | 0.02mg /L | 1 mg/L | 15μg / L | 0.5μg / L | 5mg/L |

Sources: Primary Data, (2019).

The pollution of water by heavy metals from electronic waste and other industrial sources in this particular case requires urgent attention as 1,468,767 Hararians rely on the City's various water sources for clean water. As such, the management of the City's water sources is critical. However, as matters stand, the levels of heavy metals such as lead, mercury, zinc, iron, manganese and others found in various samples in Table 6.2 above threaten some of the City's water security and the health of its public. There is a pressing need to regularly monitor the levels of heavy metals in water if health problems associated with heavy metals are to be ameliorated.

Figure 6.1: Heavy metal trend for water

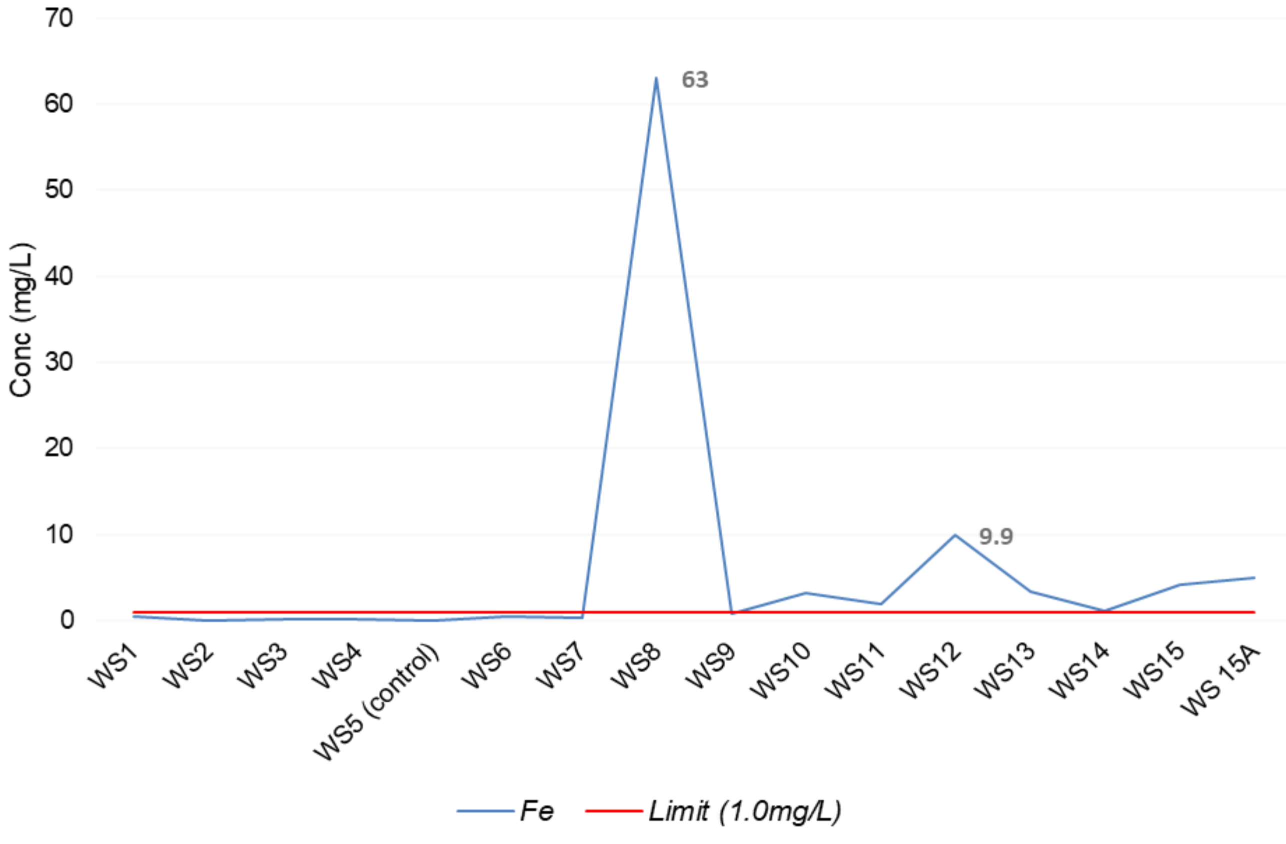



Sources: Primary Data, (2019).

### 6.3 IRON CONCENTRATION IN HARARE WATER Vs PERMISSIBLE LEVELS

Figure 6.2 below shows the levels of iron concentration in water for the 15 samples that were taken in comparison to the generally acceptable limits locally and internationally. Drinking water is very crucial and as such the management of e-waste and other heavy metals producing waste is very important as this will ensure less pollution of water. Heavy metal pollution of water can also affect negatively aquatic life which in some cases is food for humans somewhere in the food-web or chain. The fact that it is difficult to remedy heavy metals once they have polluted a given water body means that e-waste management has to be thorough to ensure the release of heavy metals into the water bodies by either underground or surface pollution is kept at a minimum. Currently, the management of e-waste in Harare shows that there is a mixed waste management approach. Evidence shows that other household solid waste and e-waste are being mixed and dumped at the official dumpsites of Pomona and Golden Quarry. These two dumpsites are both former quarry mining sites to which no engineering modifications were added before waste dumping commenced. This means no measures were taken to ensure that no underground water is polluted by e-waste and other forms of waste. As such, the two dumpsites are therefore potential sources of underground water pollution. Consequently, water tests of both sources close to the dump and dump leachates revealed above normal levels of heavy metals. This is a sign that e-waste management in Harare, Zimbabwe is not effective because a combination of e-waste and other forms of waste from industrial sites are contributing to the heavy metals resulting in soil and water pollution.

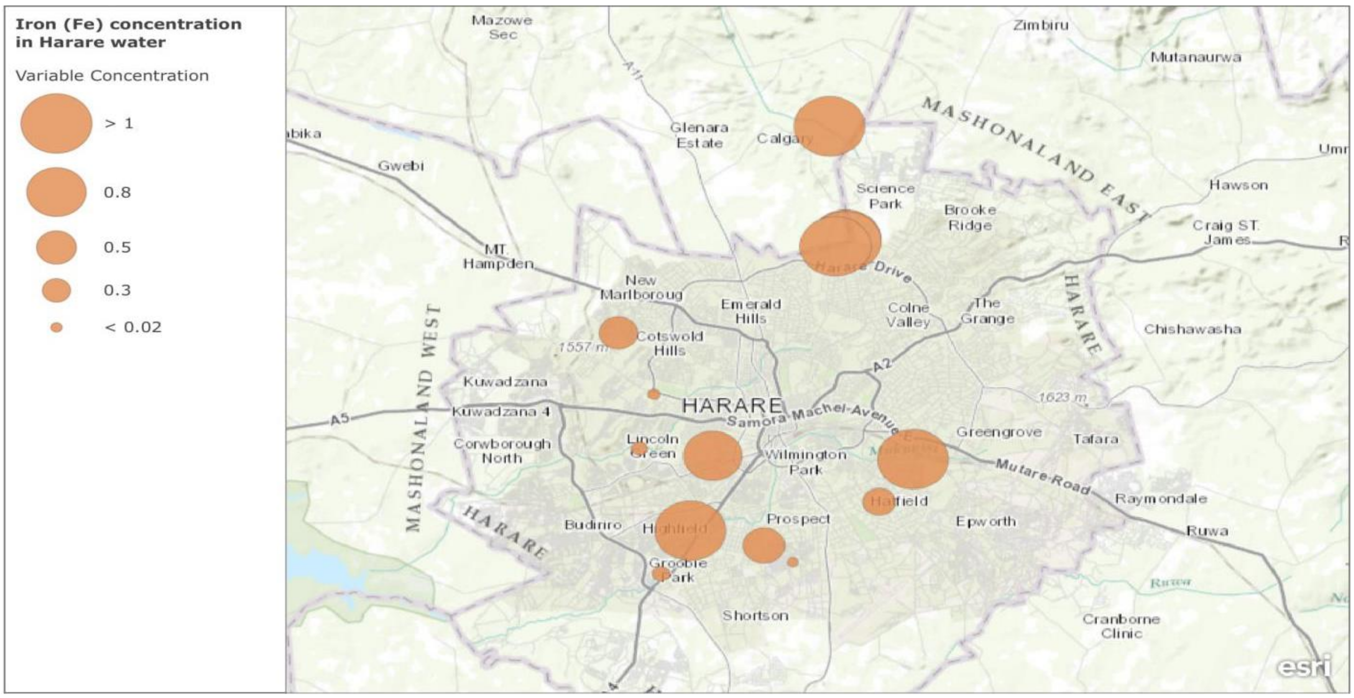
Figure 6.2: Iron Concentration in Harare Water vs Allowable Limits




Sources: Primary Data, (2019).

The sample test results were then used to come up with a map of Harare showing the area of concentration for iron. The map produced shows that the heavy metals are heavily concentrated on and around the Pomona, Golden Quarry dumpsites, as well as other roadsides dumps in Highfield, Hatfield and other areas. It is clear that since none of these dumpsites is effectively managed to ensure that no toxic substances leach into the soil, there are high chances of pollution of both soil and water within the localities. The dumpsites are the main sources of underground water pollution along the Mukuvisi River and other sources of water close to such dumpsites. This points to mismanagement of waste in general and e-waste in particular.

Figure 6.3: Map showing iron concentration in water in Harare




Sources: Primary Data, (2019).

Figure 6.3 above shows iron concentration and distribution for all 15 sites from which samples were taken in Harare. Big circles show sites with the highest concentration of iron in Harare and explain the general mismanagement of waste with iron elements in Harare which include electronic waste in such localities.

There is a general show that only sample 8 had very high levels of iron (63 mg/l); this is a location on Mukuvisi River at a crossing point in Masasa. The area had visible metals thrown in the water, including some electronic waste. This could be because of a narrow bridge there and some reeds which allows the public to drive and dump waste on that particular site from the bridge. The water is also stagnant during the dry season and cannot flow over the bridge whose drains are clogged and blocked, thus giving greater contamination of iron in water at that particular point. However, the possibility of iron and other heavy metals flowing downstream during the rainy season is great.

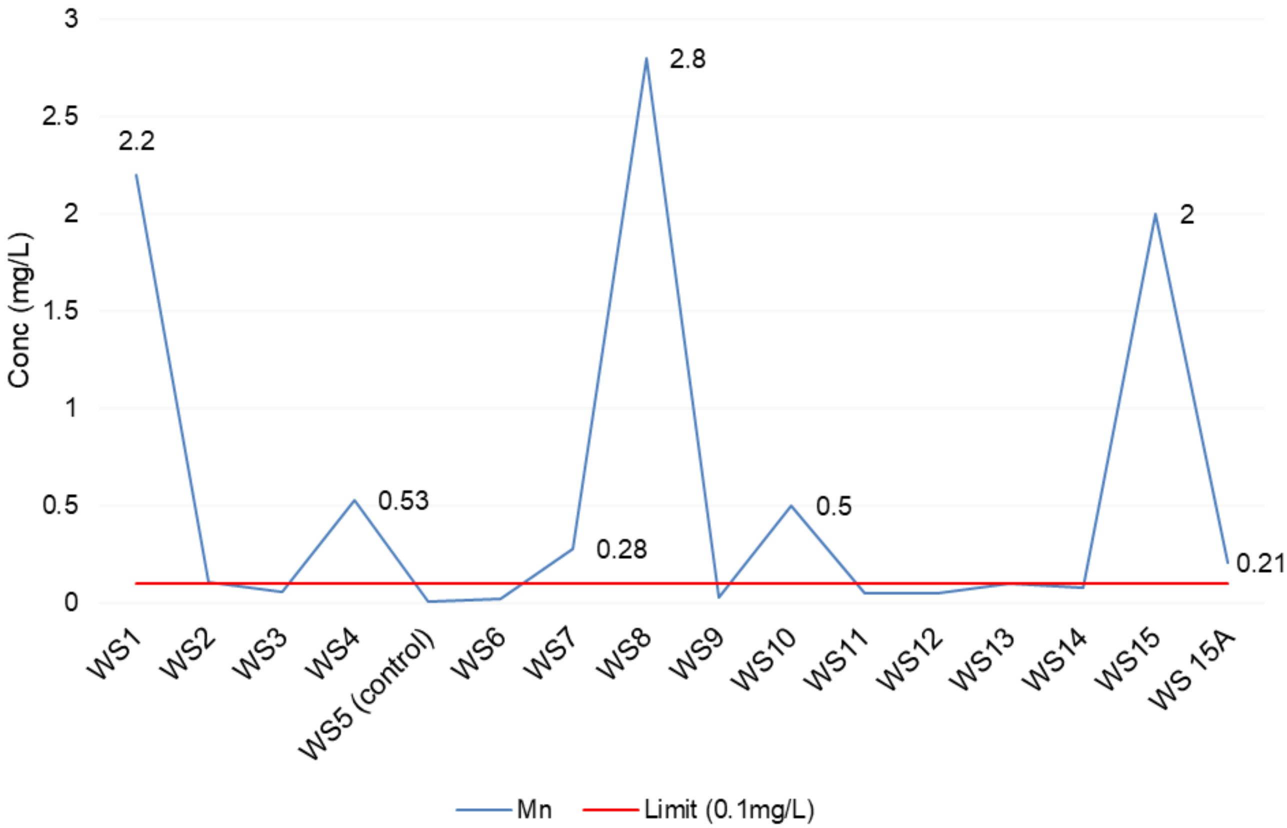
The level could also be high, not because of electronic waste alone, but also other forms of pollution from nearby industrial sites, whose waste management is ineffective and ends up being disposed of in the rivers without pre-treatment. The same was also observed by Zaranyika (1997) who lamented that industrial sources for heavy metals such as agricultural, metallurgical, electronic, pigments and paints, as well as manufacturing of batteries are dominant in the Msasa area due to the possible mismanagement of heavy metals in the area. This has resulted in the pollution of both the water and soils in the localities, all to the detriment of human health and the environment.

Sample 12 also shows an increased concentration of lead above the normal levels and this is maybe because it was taken from the leachates at the main dumpsite, Pomona. This may also explain why there is a possibility that over time there will be underground water contamination because the dumpsite is not lined and the general management of the site is ineffective, since there is no waste separation or treatment at the site. This is because it is not a proper landfill. Iron levels in Figure 6.3 above show levels above recommended limit using EMA's SI 6 of 2007 for sampling sites 8 to 15. Most iron concentration recorded on other sites is below 10 mg/L. The dumping of e-waste along with other forms of waste at official dumpsites is evidence of poor e-waste management.

## 6.4 MANGANESE CONCENTRATION IN WATER IN HARARE vs ALLOWABLE LIMIT

There are also undesirable levels of manganese in some areas of Harare, as evidenced by samples 1, 4, 8, 10 and 15 which revealed high levels ranging from 0.53 to 2.8 mg/L. There are however certain areas with normal to below normal levels.

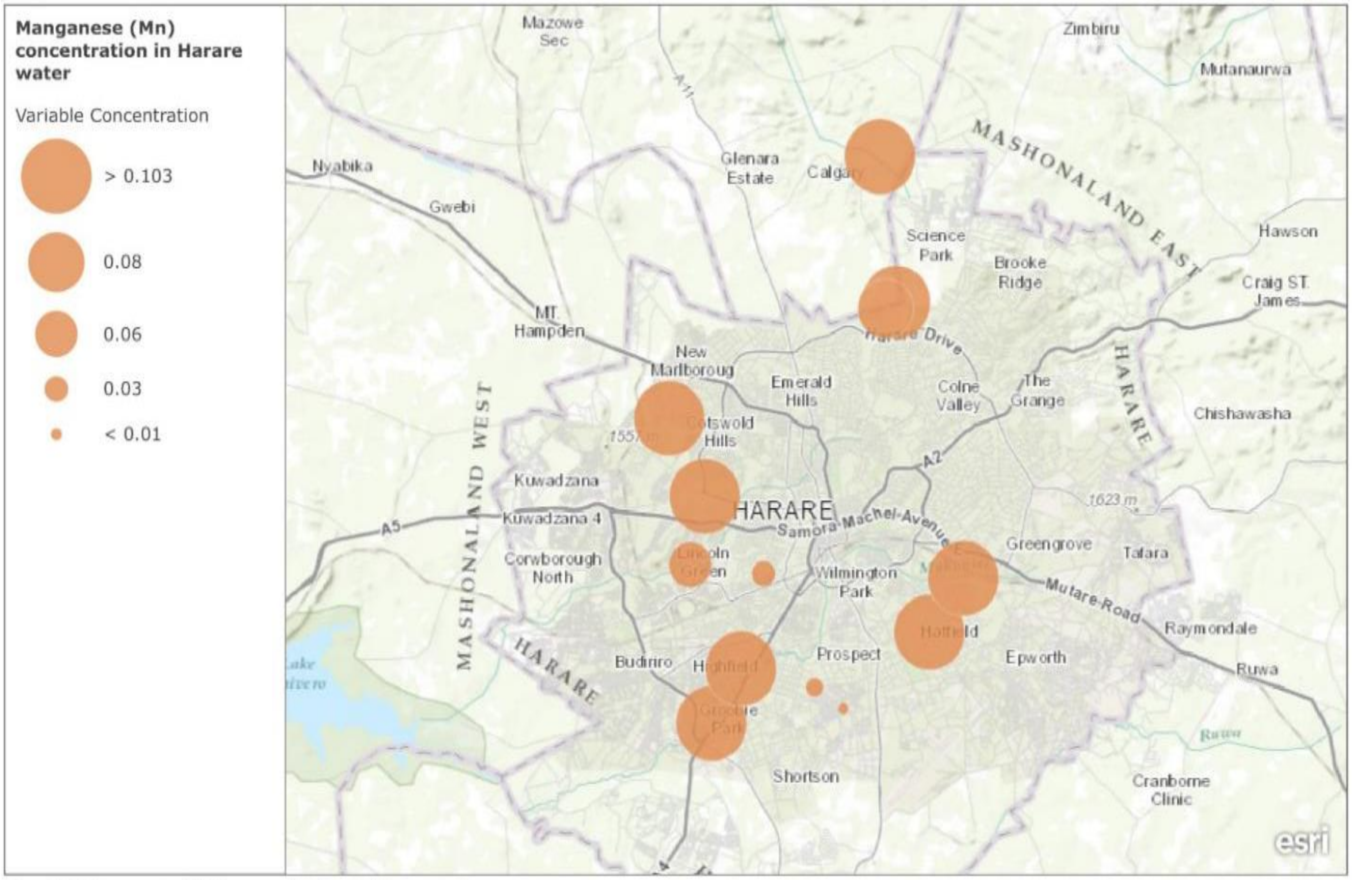
Figure 6.4: Manganese Trends Against Allowable Limits




Sources: Primary Data, (2019).

This explains a situation where there is mismanagement of e-waste as well as other forms of waste that contribute to such levels of manganese in the water. The throw-away culture as a form of waste management at household, commercial and industrial level in Harare, Zimbabwe could be the main source of these levels of manganese in the water. The other possibility could be the City of Harare's failure to collect and separate e-waste from other non-hazardous forms of waste. The information graphically depicted in Figure 6.4 shows areas with an identical concentration of manganese on the map in Figure 6.5 below.

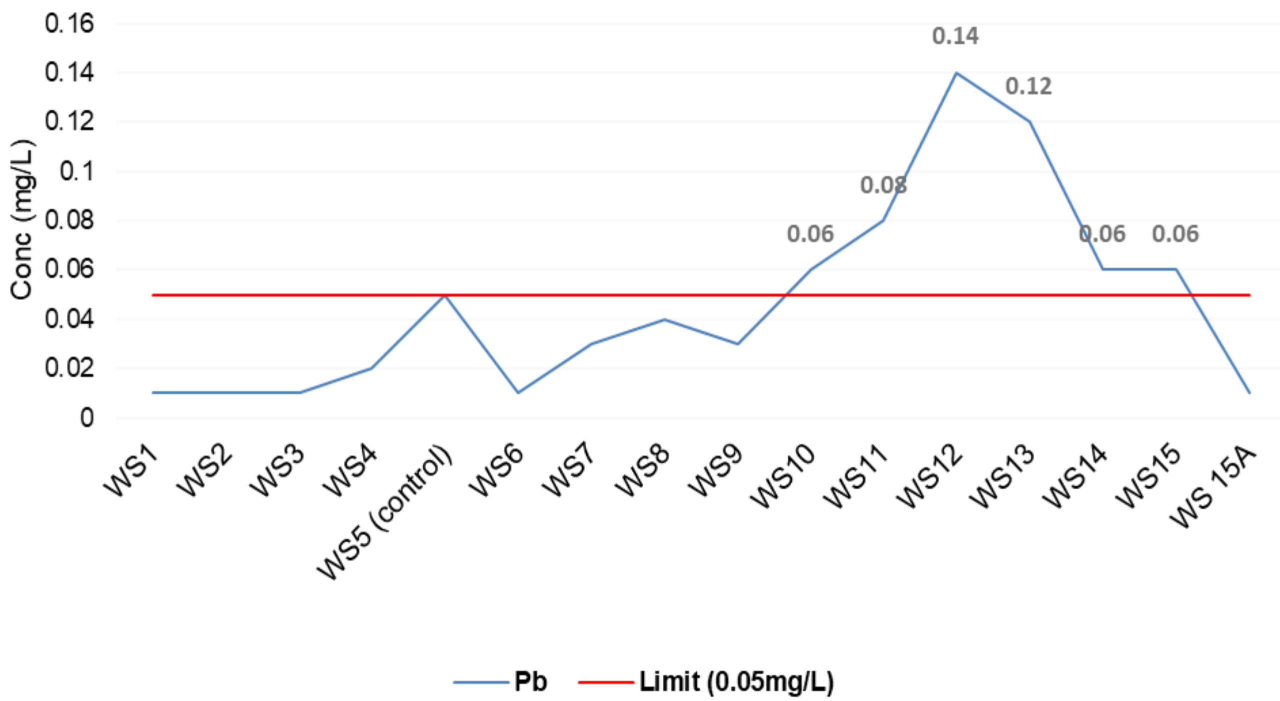
Figure 6.5: Manganese Concentration in Harare Water




Sources: Primary Data, (2019).

Figure 6.5 above shows the distribution of Mn in samples analysed with the highest recorded at sampling site number 8. The areas are generally the roadside dumps, the Pomona and Golden Quarry dumpsite, as well as points within the Mukuvisi River. The mismanagement of waste, exacerbated by electronic waste, is accountable for these levels of heavy metal pollution in Harare, and if no mechanisms are put in place to manage them, there is a high possibility that water sources will be seriously polluted. This would render the treatment of water for use by the city of Harare at the Morton Jeffry Water Works in Norton very expensive if not impossible in future. Consequently, both public health and aquatic life, most of which is fish consumed by people across Harare, will be compromised.

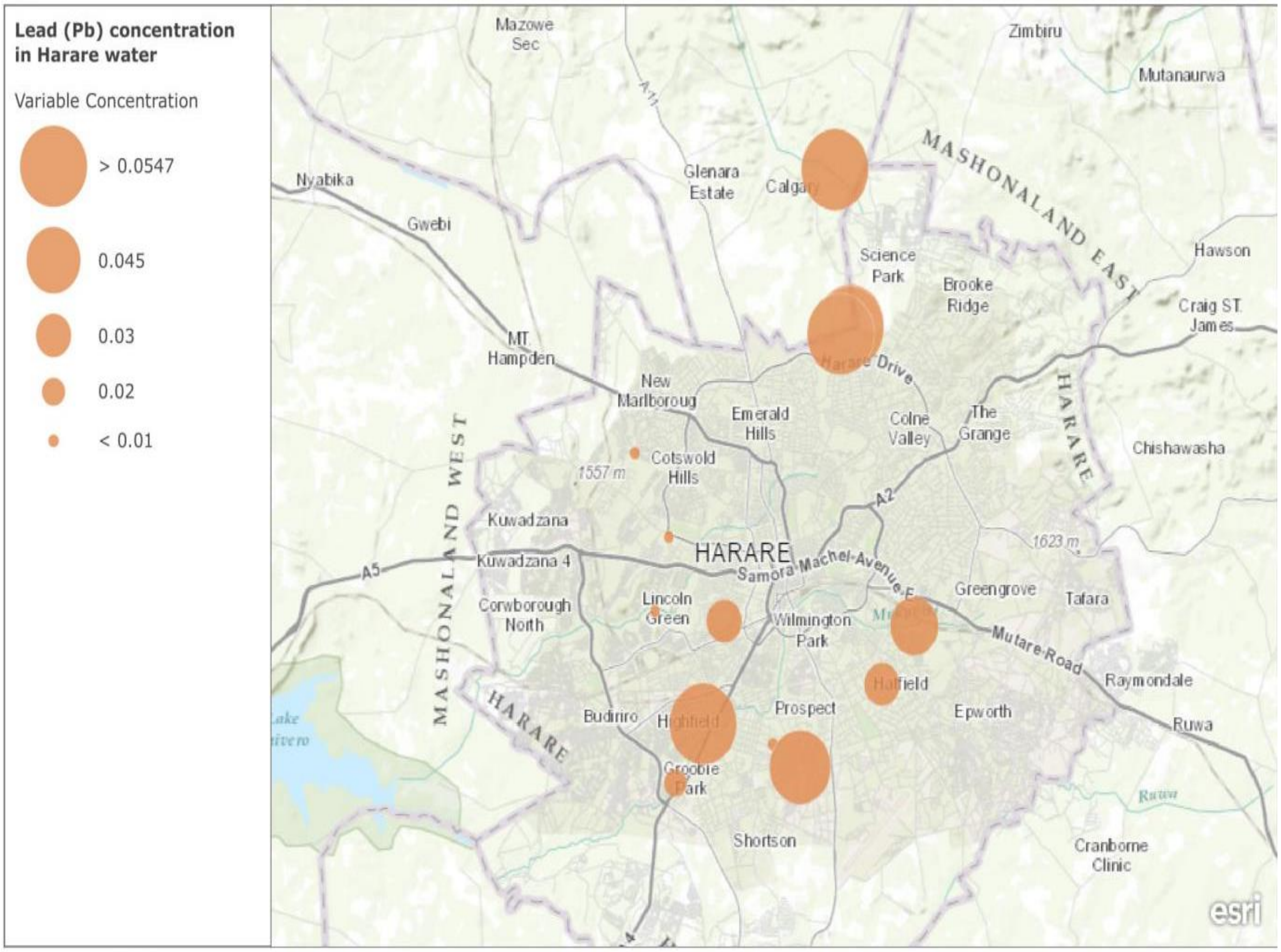
Figure 6.6: Lead Trends Versus Allowable Limits




Sources: Primary Data, (2019).

Sampling site 10 to 15 showed elevated levels of lead in water, as shown in Figure 6.6 above. These are the dumpsites and since they are not proper landfills, chances are that lead is gradually polluting the city of Harare's water and soils as well. This is against the background that it is a highly toxic metal that has caused extensive environmental contamination and health problems in many parts of the world (Jaishankak, *et al.,* 2014). To this effect, public health is at stake and ecological modernization is endangered as e-waste pollution keeps proliferating. Lead is used in the production of batteries, metal products like solder and lead can affect every organ and system in the human body and this means proper management of such materials is critical. To this end, at Pomona, batteries are commendably being dumped at a specific point. However, this special e-waste management of battery waste is negated by the fact that the place remains a dumpsite and not a landfill. Besides, the continuous management of these is unclear and hence high chances of pollution remain. The environmental justice concept thus remains compromised.

Figure 6.7: Lead Concentration and Distribution in Harare




Sources: Primary Data, (2019).

Water samples show that lead levels were higher than the World Health Organization drinking water guidelines. Lead causes teratogenic effects on human beings. The monitoring and management of e-waste are therefore critical if teratogenic effects are to be reduced and the good health and environment of the residents of Harare are to be enhanced.

## 6.5 SOILS

The soil samples collected for monitoring leaching of e-waste, the following parameters were investigated: mercury, arsenic, lead, cadmium, cobalt, iron and zinc. Among the seven parameters, trends of Hg, As and Cd were not plotted since these do not naturally occur at high levels in the soil. The soils were taken from across the city of Harare and a total of 33 samples were picked at various points to establish the levels of heavy metals in them. This then gave an estimate of what and how e-waste, which is the greatest contributor of heavy metals in soils is managed. The evidence showed that a lot needs to be done in both the general and e-waste management of Harare.

## 6.6 SOIL RESULTS

The results of the soil analysis for arsenic (As), cadmium (Cd), cobalt (Co), iron (Fe), mercury (Hg), zinc (Zn) and lead (Pb), are tabulated as shown in Table 6.3 below.

Table 6-3: Soil results: Arsenic, Cadmium, Cobalt, Iron, Lead, Mercury and Zinc

| Lab Ref | Sample Number | As | Cd | Co | Fe | Pb | Hg | Zn |
|---|---|---|---|---|---|---|---|---|
| 186018 | Sample 1 | 0.25 | 0.25 | 10 | 7750 | 25.75 | 0.75 | 30 |
| 186019 | Sample 2 | 18 | 16 | 10 | 300 | 1625 | 1.7 | 637.5 |
| 186020 | Sample 3 | 21 | 0.25 | 4.75 | 1525 | 12.5 | 0.15 | 97.5 |
| 186021 | Sample 4 | 21.5 | 1.5 | 3.25 | 5400 | 440 | 3.75 | 262.5 |
| 186022 | Sample 5 | 1.45 | 0.75 | 7.75 | 5400 | 45 | <0.01 | 112.5 |
| 186023 | Sample 6 | 1.35 | 0.5 | 6.25 | 3200 | 25 | <0.01 | 250 |
| 186024 | Sample 7 | 0.95 | <0.01 | 0.5 | 2025 | 17.5 | 0.075 | 40 |
| 186025 | Sample 8 | 1.6 | <0.01 | <0.01 | 1825 | 25 | 0.775 | 100 |
| 186026 | Sample 9 | 1.85 | <0.01 | 0.75 | 1775 | 15 | <0.01 | 50 |
| 186079 | Sample 10 | 4 | <0.01 | 9.75 | 8450 | 172 | 0.18 | 130 |
| 186080 | Sample 11 | 1.38 | 0.25 | 5 | 906.25 | 32.5 | <0.01 | 30 |
| 186081 | Sample 12 | 1.13 | <0.01 | 1.75 | 493.75 | 18.5 | <0.01 | 45 |
| 186082 | Sample 13 | 0.78 | <0.01 | 1.75 | 218.75 | 16.5 | 0.05 | 27.25 |
| 186083 | Sample 14 | 1.98 | 0.75 | 4.25 | 2200 | 57.5 | 0.18 | 562.5 |
| 186084 | Sample 15 | 0.65 | 0.25 | 2.5 | 1962.5 | 27.5 | <0.01 | 80 |
| 186085 | Sample 16 | 10 | 1 | 10 | 1562.5 | 70 | <0.01 | 612.5 |
| 186086 | Sample 17 | 0.9 | <0.01 | 5.25 | 737.5 | 37.5 | <0.01 | 45 |

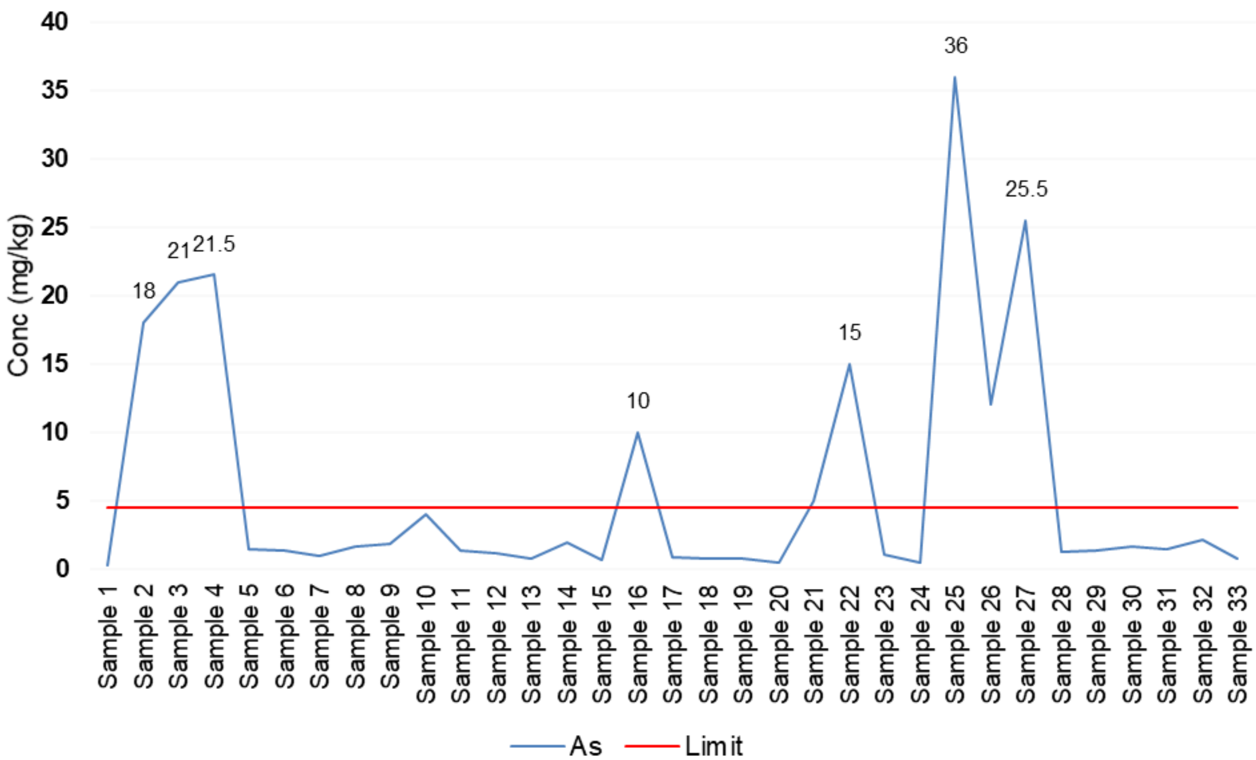
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 186087 | Sample 18 | 0.78 | 0.25 | 6.75 | 856.25 | 20 | 0.03 | 330 |
| 186088 | Sample 19 | 0.73 | <0.01 | 39.25 | 3300 | 7.75 | <0.01 | 13 |
| 186089 | Sample 20 | 0.45 | <0.01 | 30.25 | 6025 | 30 | <0.01 | 612.5 |
| 186090 | Sample 21 | 5 | <0.01 | 22 | 4312.5 | 31.25 | 1.05 | 63.75 |
| 186091 | Sample 22 | 15 | 0.5 | 10.25 | 3790 | 255 | 0.175 | 243.75 |
| 186092 | Sample 23 | 1075 | 6.25 | 30 | 5212.5 | 775 | 0.75 | 275 |
| 186093 | Sample 24 | 0.45 | 1 | 12.5 | 6387.5 | 6900 | 0.425 | 240 |
| 186094 | Sample 25 | 36 | <0.01 | 6 | 9800 | 1012.5 | 0.225 | 55 |
| 186095 | Sample 26 | 12 | <0.01 | 9.5 | 3125 | 56.25 | 3.5 | 90 |
| 186096 | Sample 27 | 25.5 | <0.01 | 6.75 | 3100 | 100 | 0.45 | 45 |
| 186097 | Sample 28 | 1.25 | 4.75 | 5.5 | 1618.75 | 140 | 1.175 | 937.5 |
| 186098 | Sample 29 | 1.375 | <0.01 | 6.75 | 1293.75 | 240 | 0.875 | 60 |
| 186099 | Sample 30 | 1.6 | 0.25 | 1 | 687.5 | 125 | 0.25 | 82.5 |
| 186100 | Sample 31 | 1.4 | 1.25 | 7.75 | 6675 | 23.75 | 0.375 | 2700 |
| 186101 | Sample 32 | 2.125 | <0.01 | 5 | 9650 | no sample | <0.01 | 896.3 |
| 186102 | Sample 33 | 0.8 | <0.01 | 15.75 | 5087.5 | 157.5 | <0.01 | 78.75 |

Sources: Primary Data, (2019).

## 6.7 ARSENIC CONCENTRATION IN HARARE SOILS

Arsenic is a known human carcinogen. Its presence in the soil due to e-waste mismanagement and other forms of waste is a danger to people and the environment. Figure 6.8 below shows that arsenic is present in most dumpsite areas in Harare. Most samples taken from the Pomona and Golden quarry dumpsites had high levels of arsenic. This implies that there are pockets of arsenic in Harare, which if not properly managed, might percolate and pollute water sources. This arsenic concentration in various soil samples is shown in Figure 6.8 below.

Figure 6.8: Arsenic Trends for Soils in Harare

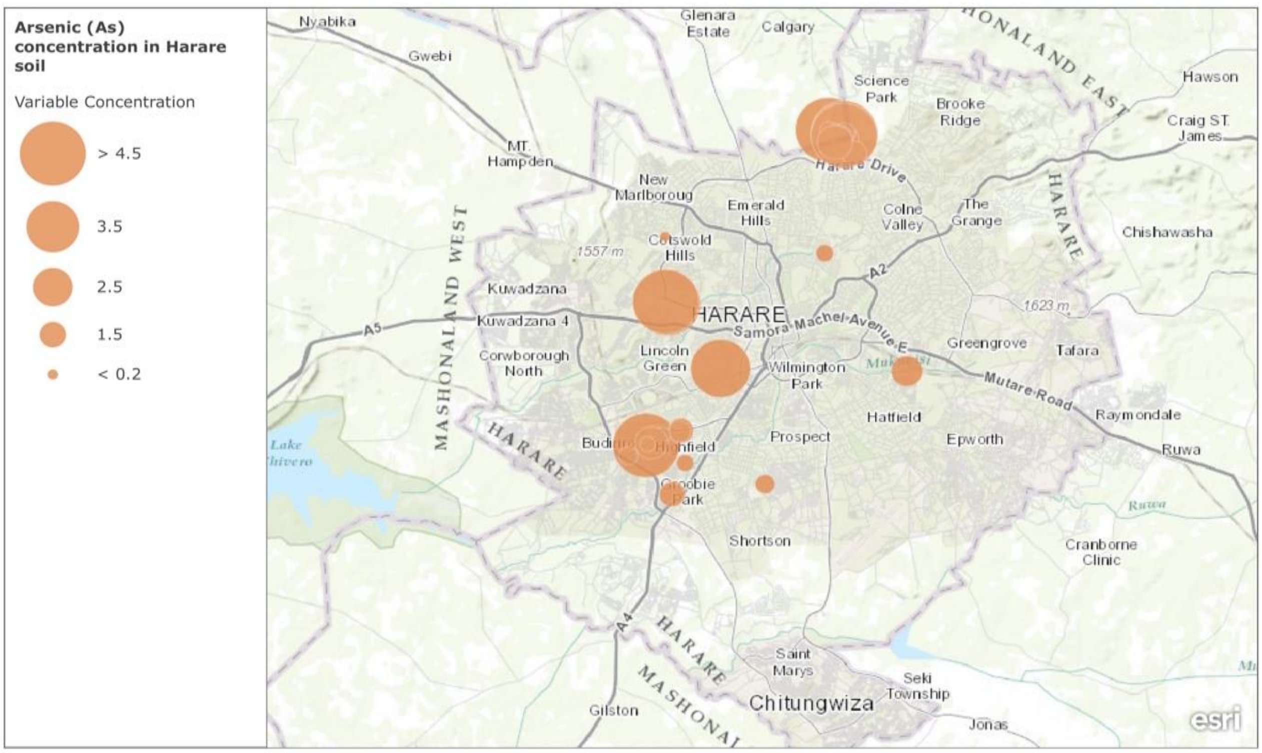



Sources: Primary Data, (2019).

The occurrences of arsenic in Harare's soils are dominant in areas where e-waste is dumped. Judging by the analysis results, it appears the bigger the dump the higher the concentration of arsenic. Although some roadside dumps in Mbare and Highfield presented high levels of arsenic, Harare's two main dumpsites had the highest. These two testify to the likely mismanagement of e-waste and other heavy metal related waste in Harare. Areas such as Bluffhill, Waterfalls and Mandara had low levels of arsenic. The management of these areas needs to be meticulously sustained to avoid any further pollution. The construction of a proper landfill would, to some extent ensure that proper management of waste and in particular e-waste is undertaken. Doing so would greatly prevent the pollution of underground water and soils where urban agriculture is taking place and food for human consumption, produced.

Most importantly, since these small dumpsites are considered very fertile land for urban agriculture and yet are sources of health-threatening heavy metals, their effective management is imperative. Indeed, as observations attested, when some urban residents prepare such land for farming, they sometimes burn the grass and other forms of waste which include e-waste to clear and prepare the land for their crops. Doing so not only pollutes the air, at times the land-clearers involuntarily breathe in air that is contaminated with heavy metals.

Figure 6.9: Arsenic Concentration in Soils in Harare



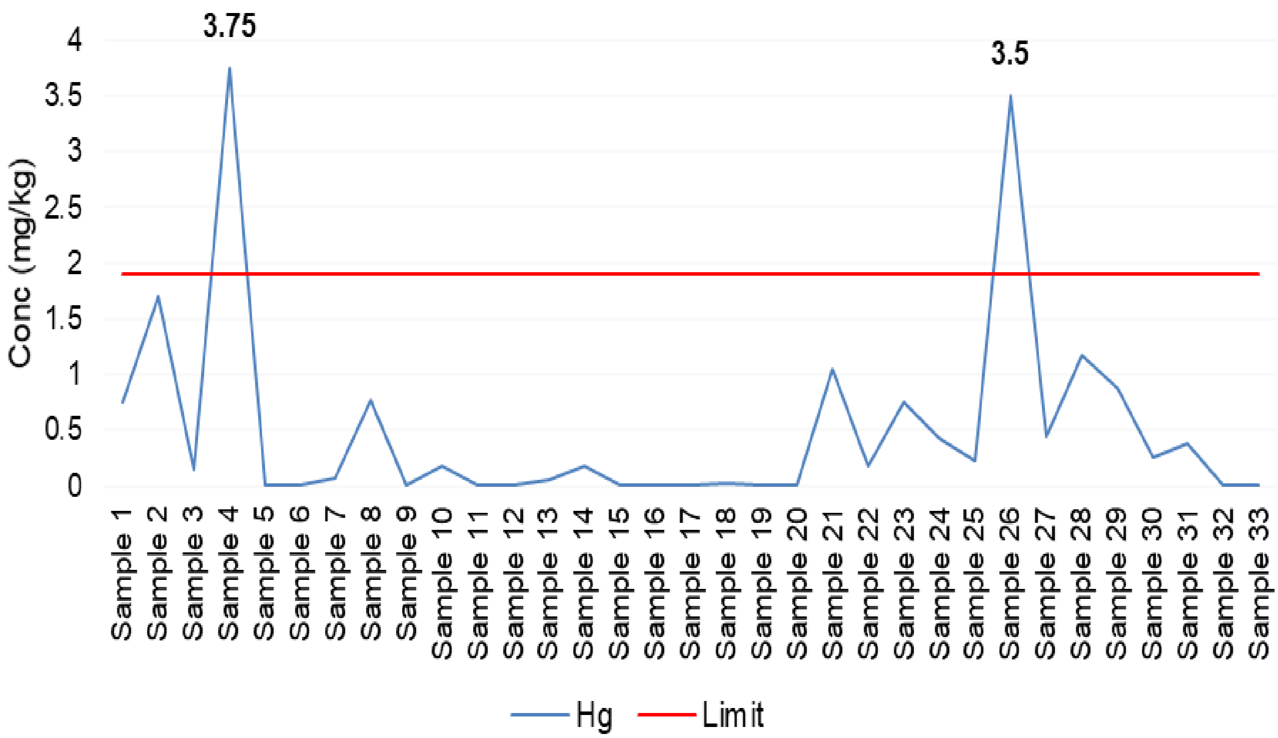
Sources: Primary Data, (2019).

Arsenic is also found in paints, dyes, metals, drugs, soaps and semi-conductors. Certain fertilizers and pesticides can release high amounts of arsenic into the environment. This means that not only e-waste is responsible for the concentration indicated on map 6.9 above, as other sources might also be contributing factors. These other players could be industries around the city and their various activities. However, the fact that it is difficult to ascertain the source of the heavy metals is testimony that the results are most likely influenced by e-waste related heavy metals. Given this, the management of the dumpsites, e-waste and other heavy metal producing activities would greatly contribute towards reducing heavy metal pollution.

### 6.8 MERCURY CONCENTRATION IN HARARE SOILS

Mercury concentration was found to be present on two of Harare's dumping sites, the Golden Quarry dumpsite, from where sample 4 was collected, as well as from the Pomona dumpsite, from where sample 26 was collected. The rest of the samples collected showed levels of mercury below acceptable limits. This is shown in graph Figure 6.10 below. Based on the presented sample results, it can be concluded that, despite some dumping of waste on Harare's roadsides, there is low mercury pollution in the greater part of Harare. It is only on the City's two main dumpsites where unacceptable mercury pollution was detected. Consequently, the proper management and monitoring of dumpsite facilities are imperative as these mercury polluted sites might become nuclei for e-waste related heavy metal pollution. If not immediately attended to, there is also the possibility of the mercury permeating into the surrounding environment and infiltrating the underground water system.

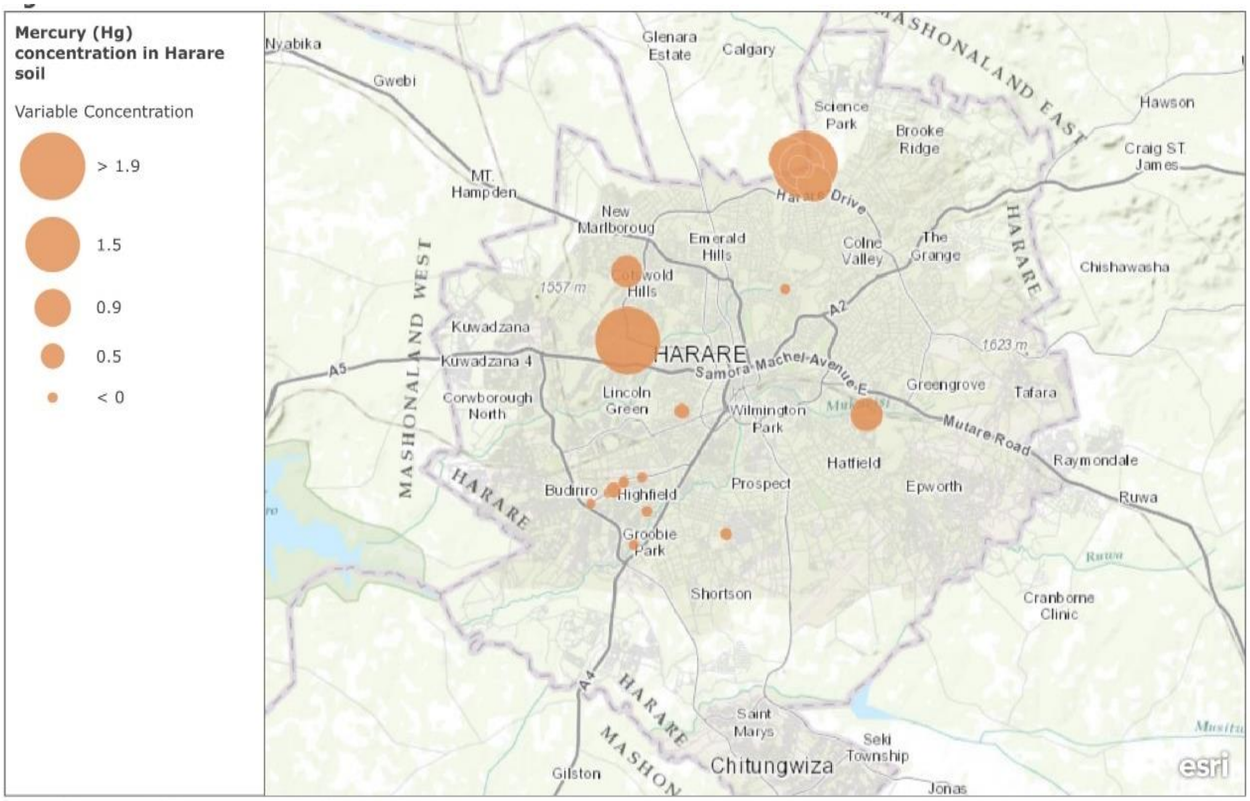
Figure 6.10: Mercury Trends in Soils in Harare




Sources: Primary Data, (2019).

The vaporization of metallic mercury and demethylase mercury is also of concern due to uncontrolled fires at the two main dumpsites in Harare. A similar observation by Jerie, (2005) reports that the Golden Quarry dumpsite caught fire on 28 August 2000 and the Fire Brigade battled for a week to extinguish it. Mercury is used in dental fillings, switches, light bulbs and batteries, mercury in soil and water is converted by microorganisms to methyl mercury a bio-accumulating toxin. When mercury mixes with water it is converted into methyl mercury which easily bio-accumulates into wildlife and aquatic species (Pinto, 2008). Mercury is one of the most toxic yet widely used metals in the production of electrical and electronic appliances such as fluorescent lights, Liquid Crystal Display (LCDs) and batteries. It is one of the most commonly used metals in EEE (Pinto, 2008). Its concentration in Harare is shown in Figure 6.11 below where it is clear that mercury is mostly found at the dumpsites more than anywhere else in Harare.

Figure 6.11: Mercury Concentration in Harare

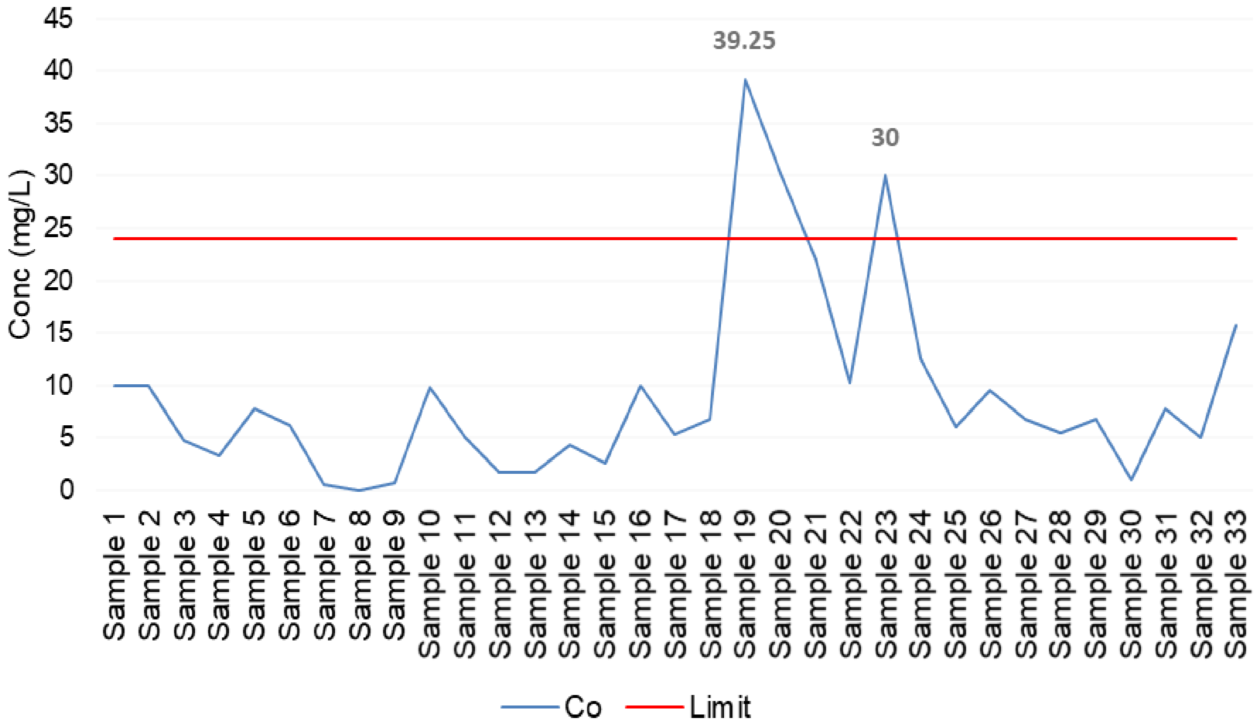



Sources: Primary Data, (2019).

## 6.9 COBALT CONCENTRATIONS IN HARARE SOILS

There was significant Cobalt (Co) contamination in the soil samples, especially samples 19 to 23 taken from Pomona the main dumpsite for Harare. This means that over time there is a likelihood of bio-accumulation and bio-magnification of Cobalt at the dumpsite. This will in all probability affect the health of recyclers and also pollute the soils and plants around the dump. Some samples were taken from areas with visible e-waste and chances are that the levels of Co in such soil could be a product of electronic waste mismanagement. This explains the need for proper and effective e-waste management in Harare, Zimbabwe as strains of e-waste pollution were already visible and could multiply as more electronic goods are produced, sold, used and later discarded. Figure 6.12 shows that only a small part of Harare is contaminated by the above normal concentration of cobalt. This points to the fact that the levels of pollution due to cobalt are not yet wild and serious. Given this, a legal instrument to deal with e-waste management will significantly reduce pollution related to heavy metals. Controls in the indiscriminate dumping of e-waste will, in all likelihood, reduce the levels of heavy metals in the soil and water bodies.

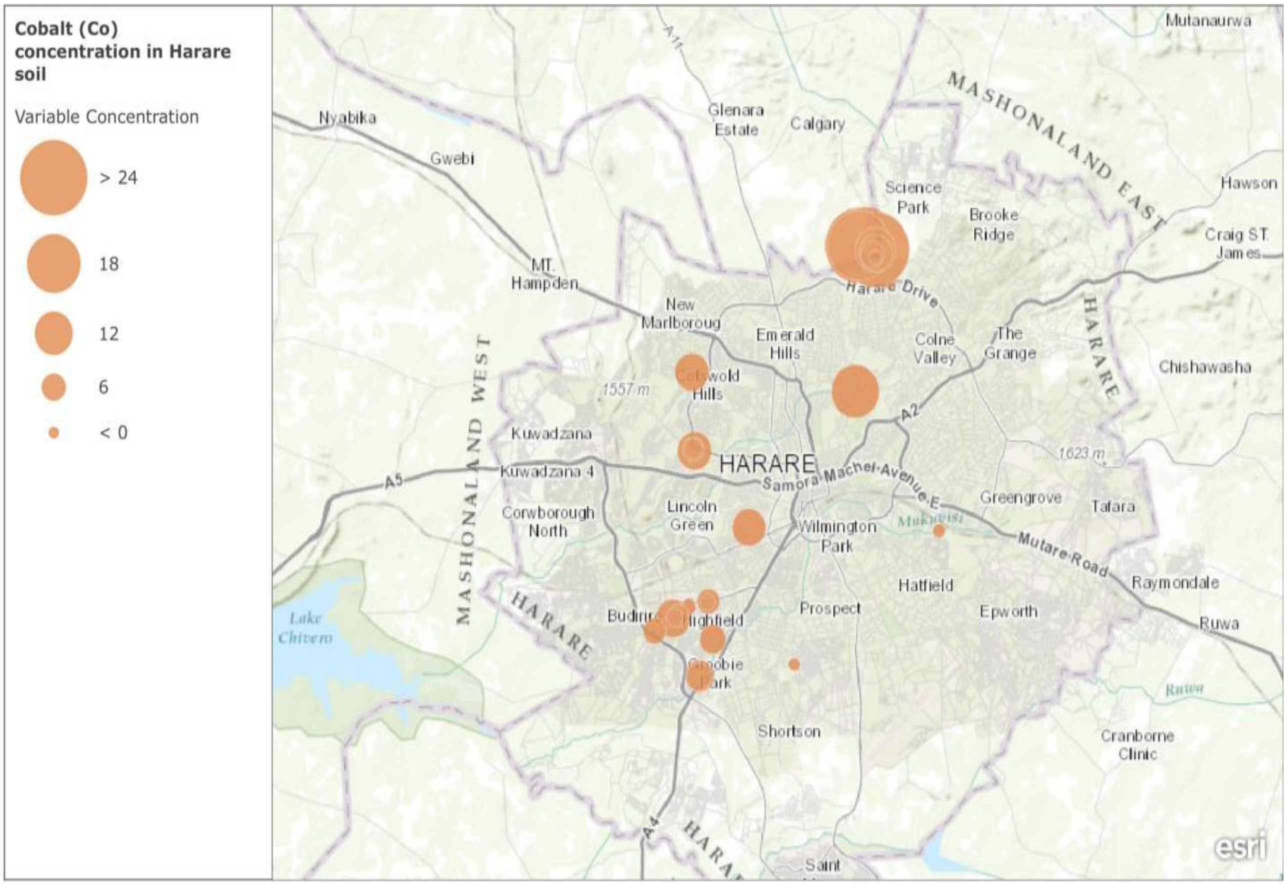
Figure 6.12: Cobalt Trend in Soil for Harare




Sources: Primary Data, (2019).

The map below (Figure 6.13) shows that the concentration of cobalt is not very serious, except at the main Pomona dumpsite where it is > 24 mg/L. In some places, the concentration is very low, < 0 mg /L. Notably, it is not all areas in Harare that are polluted with heavy metals. It must however be noted that there is a need for proper e-waste management as failure to properly manage e-waste may cause serious pollution by heavy metals. Human health and other forms of life in the environment would then be affected.

Figure 6.13: Cobalt Concentration in Harare

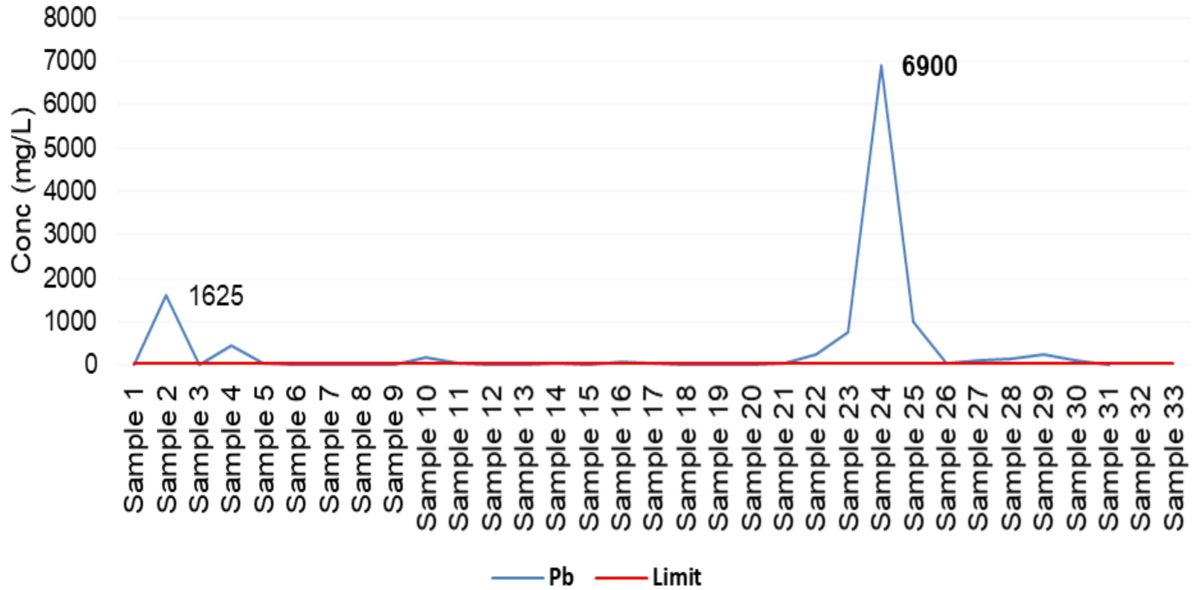



Sources: Primary Data, (2019).

## 6.10 LEAD CONCENTRATION IN HARARE SOILS

Zhang et al., (2012) report that e-waste areas are often contaminated by heavy metals. Lead is highly toxic to humans, animals and plants and is used as a major component of solder in electrical and electronic products and lead-acid in batteries (Kuper and Hosjsik, 2008). This means it can decompose and potentially pollute the environment, irreversibly affect, through inhalation, ingestion and dermal intake, those who come into contact with contaminated environments. Figure 6.14 below shows that some areas are polluted with lead in Harare and that the possibility of people being affected is there since they live, and have daily interaction with the contaminated sites. Below is a graph (Figure 6.14) showing the Lead trend in Harare against normal levels.

Figure 6.14: Lead Trend in Soil for Harare

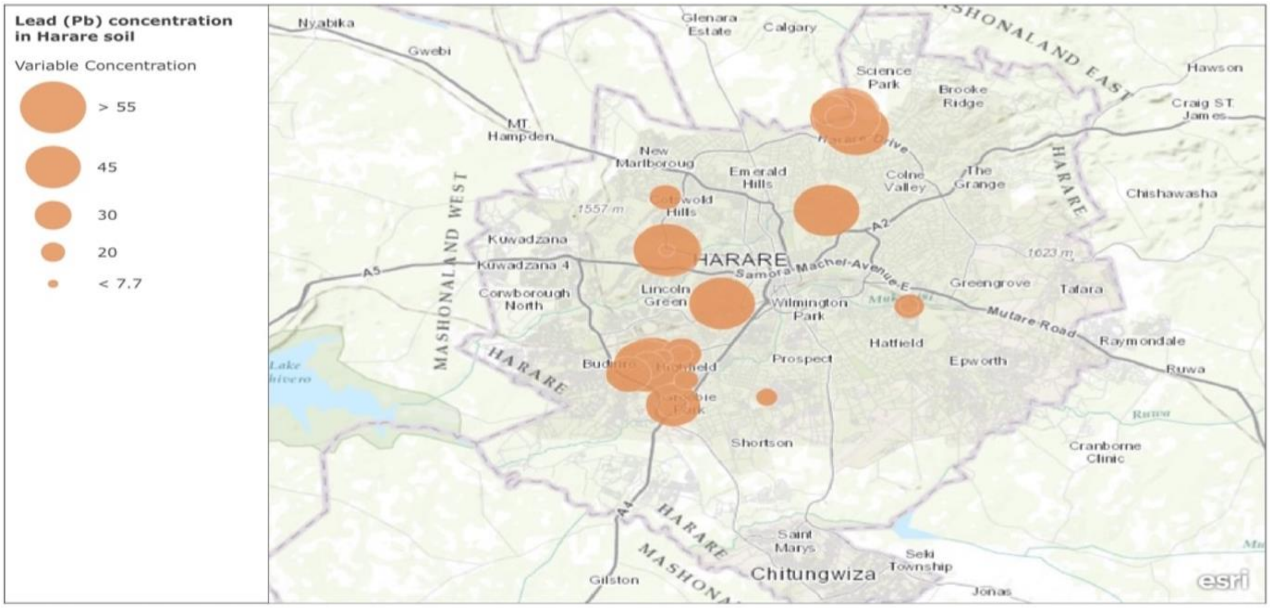



Sources: Primary Data, (2019).

The information presented in Figure 6.14 above calls for the proper management of e-waste. However, the focus seems to be on other waste-related diseases such as Cholera and Typhoid than e-waste related diseases. This is perhaps because these are rarely known compared to waste-related diseases. There is little if any research work on e-waste related heavy metals and their effects on the environment and people's health.

The mismanagement of electronic waste in Harare is seen, not only because of the concentration of lead in the soil and water samples collected, but also by the visible presence of e-waste on dumpsites as observed across the city. It is also evident in the lack of legislation on e-waste as well as the domestication of international conventions on the management of dangerous substances. Since the problems seem to be budding, they must be quickly addressed to avoid serious future problems. Figure 6.15 below shows the distribution of lead concentration in Harare.

Figure 6.15: Lead Concentration in Harare Soils




Sources: Primary Data, (2019).

The detection of high concentration levels of heavy metals such as arsenic, mercury, cadmium and others demonstrate a significant pollution anomaly, a potential threat to the aquatic ecosystem and human health. Exceeding maximum allowable concentrations is proof of the mismanagement of e-waste. This should be addressed to avoid serious pollution problems in future.

## 6.11 CHAPTER SUMMARY

The management of e-waste in Harare, Zimbabwe is critical as heavy metals are dangerous to human health and the environment in general. As the economic hub of Zimbabwe, Harare is increasingly becoming the country's pollution centre. Considering that there is a multiplicity of already existent poor waste management related problems, this critical addition of fast polluting e-waste is complicating waste management in Harare. Although e-waste is still in its infancy, it has already caused serious threats to the environment and humanity. The water bodies supplying water to the city of Harare are also threatened by the birth of e-waste as heavy metals permeate from e-waste and pollute the water sources. Streams and rivers are the most endangered ecosystems worldwide and as such e-waste management is critical, as any negligence will result in severe environmental pollution in Harare, Zimbabwe.

# Chapter 7

## UNDERSTANDING OF THE IMPACT OF E-WASTE MANAGEMENT

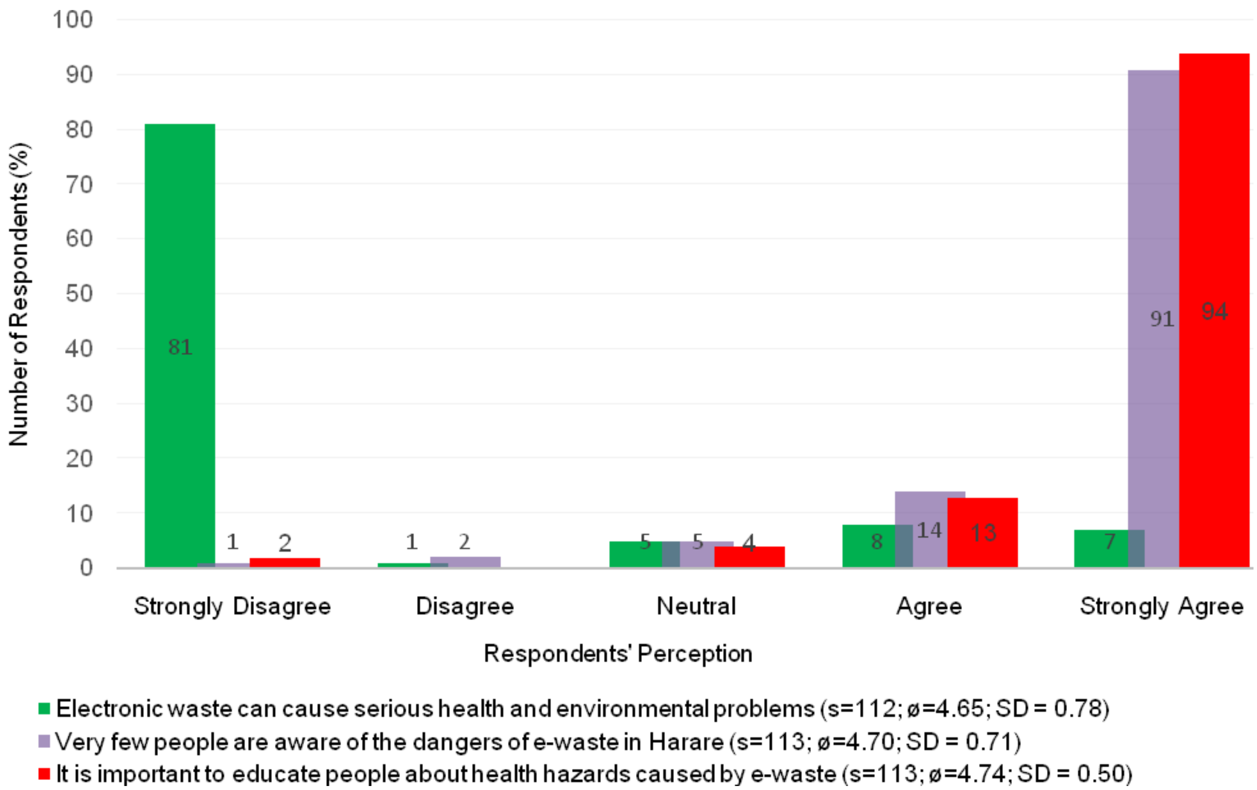
### 7.1 INTRODUCTION

The preceding chapter assessed the effectiveness of e-waste management strategies being used in Harare. This chapter sought to determine the population of Harare's understanding of the phenomenon of electronic waste management. Specifically, this chapter focuses on levels of understanding e-waste management by the population of Harare, awareness of e-waste health risks, the importance of awareness campaigns, e-waste health hazards, sources of electronic wastes, capacity by the City of Harare to treat and dispose of e-waste, challenges in e-waste management in Harare and causes of poor e-waste management in Harare. The chapter starts by looking at the levels of understanding of e-waste management among the population of Harare.

### 7.2 E-WASTE MANAGEMENT COMPREHENSION LEVELS IN HARARE

One of the study objectives was to establish the extent of some Harare city-dweller’s understanding of the e-waste phenomenon. This was deemed necessary because residents’ understanding of e-waste has a direct bearing on the way they would participate in e-waste management. In this vein, respondents were asked whether e-waste had negative effects on the environment and public health. Of these respondents, 81 out of 102 showed that they were unaware of any, as they strongly disagreed with the statement. As such, in all likelihood, they might not have a positive attitude towards its management. Conversely, it was established whether people are aware of the dangers of e-waste. 91% of the respondents strongly agreed that they are ill-informed about the dangers inherent in e-waste. In this regard, efforts to properly manage e-waste might be limited, as the beneficiary population of e-waste management would be unappreciative of such efforts. Respondents’ perceptions about waste management are presented in Figure 7.1 below.

Figure 7.1: E-waste Management Comprehension by the Population of Harare




Sources: Primary Data, (2019).

Having established that Harare, Zimbabwe is not aware of the problems e-waste has to the environment and their health, the research also sought to find a way forward given the established background. The respondents indicated that educating people on e-waste management was a critical component of its management. The concept of education as a critical e-waste management tool is discussed in detail below.

## 7.3 IMPORTANCE OF CONSCIENTIZING POPULATIONS ON E-WASTE HEALTH HAZARDS.

To gauge Harare's level of understanding of e-waste management, the researcher posed a question on whether it is imperative to educate people about health hazards posed by e-waste. Ninety-four (94) participants (83.2%) strongly agreed that people should be educated on the health hazards associated with e-waste. Thirteen (13) of the respondents constituting (11.5 %) agreed that the population should be made conscious of the health hazards associated with e-waste. In total, 94.7 % of the participants echoed the same sentiments that it is important to educate people about e-waste health hazards. This is critical to the management of e-waste as an understanding by the population of the dangers of e-waste will promote its proper management.

An interview with the representative of the Ministry of Local Government in the Urban Local Authorities Division disclosed that in Harare, the population needs to be educated concerning the rampant and indiscriminate throwing of litter anywhere in the city. The representative attributed the practice to the huge size of Harare's population and the inability of the city to collect waste. In addition, the representative indicated that as a Ministry, they had not yet encountered any problems with electronic waste. This is despite the Ministry being aware that the Harare City Council dumps mixed refuse at Pomona dumpsite. The Municipality does not separate the refuse and relies on searchers and pickers at the City's dumpsites whose livelihood is derived from sifting through the garbage and sorting it into various types for onward selling to companies involved in recycling.

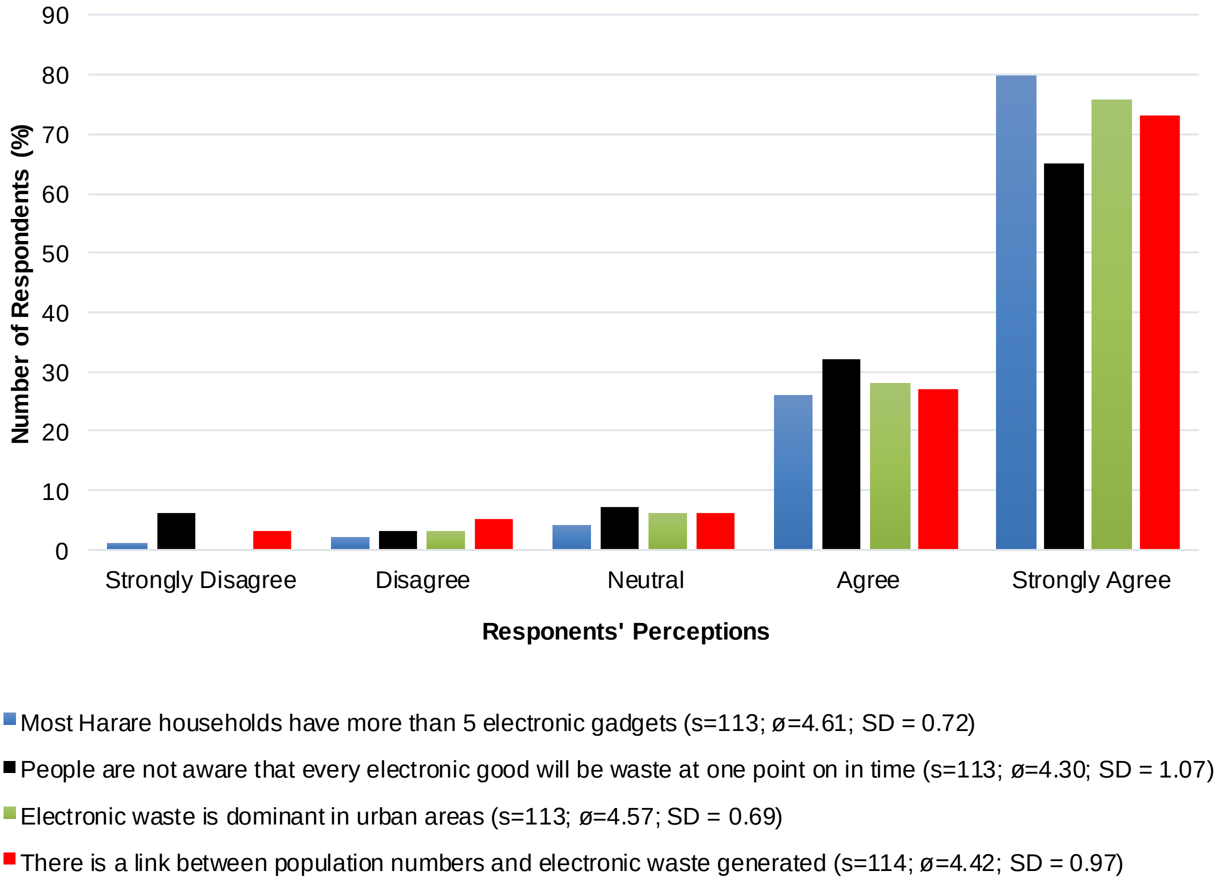
Based on the above, Harare does not have proper e-waste management strategies in place. Otherwise, it would not rely on scavengers or informal waste pickers for waste separation. Daily, Harare's dumpsites of Golden Quarry and Pomona each barely have more than 700 scavengers according to records kept at the gates for those who officially pay to scavenge. Given the size of both the city, its 4141849 dwellers, the industrial and commercial entities in Harare, and the refuse generated every day, the scavengers cannot be relied upon to sort and expertly process the City's mixed waste. Besides this, dumpsite searchers and pickers do not separate waste per se, rather, they look for what is subjectively useful and saleable. With the advent of e-waste, the management of waste has become even more complex for Harare, resulting in poor e-waste management. Plate 7-1 shows a searcher-picker or scavenger collecting recyclable and reusable materials at the Golden Quarry dumpsite for onward selling in the townships of Magaba, Gazaland, Siyaso, Machipisa and Mbare.

Plate 7-1: An Individual Collecting Recyclable and Reusable materials

Source: Field Survey, (2019).

Interviews with scavengers at both Pomona and the Golden Quarry dumpsites revealed that they regarded scavenging as a survival strategy. They were oblivious to the possible dangers and side effects of working with e-waste daily without wearing PPE. Some were equally unaware of the important role they play in the City's waste management matrix. To them, they derive their survival from searching and picking through waste and nothing more. The situation in Harare tells a story that e-waste and waste management, in general, is unimportant as scavenging and probably recycling are duties for the poor and uneducated. This was revealed during interviews with the scavengers at Pomona. Apparently, no professional considers it dignified to work with and around e-waste. The recycling of e-waste, therefore, does not attract serious public and private players at the moment in Harare, Zimbabwe. The officials manning the dumpsite also indicated that there are no hard and fast rules surrounding scavenging. As such, people come and pay a small amount to spend a month looking for various items to include e-waste. This simply points to an unorganised waste management system whose future is likely to be complex especially when we look at the rate at which e-waste is increasing annually the world over.

Figure 7.2: Respondents' Sentiments on E-waste Management



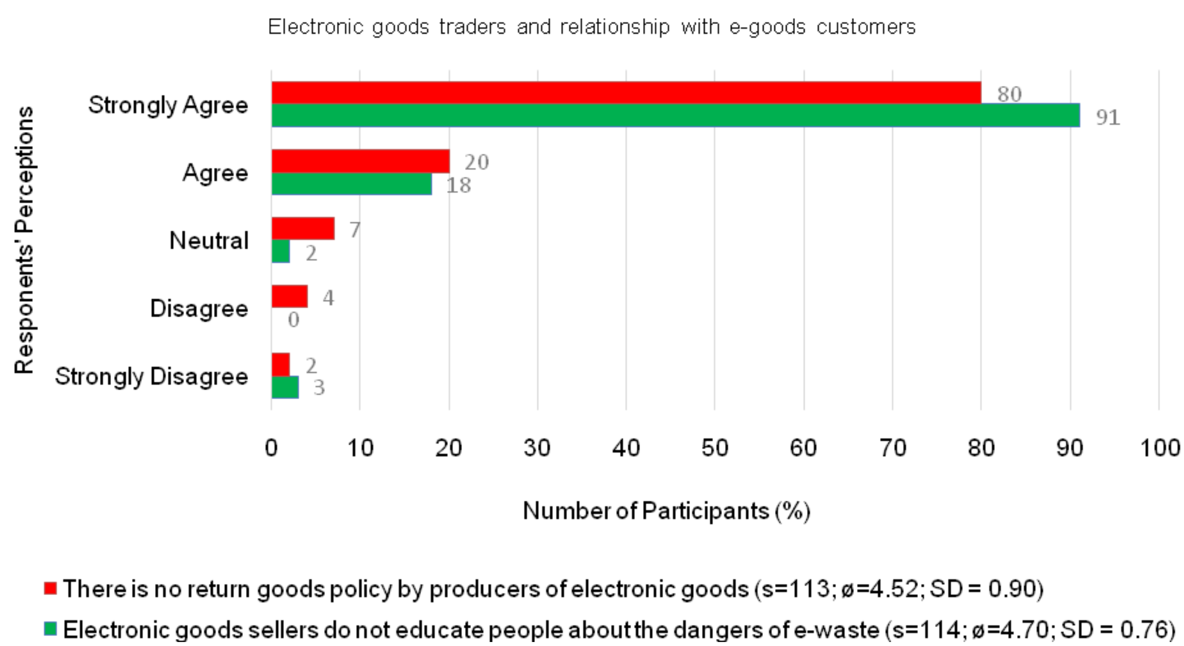

Source: Primary Data, (2019).

Figure 7.2 above shows that 80 participants or 70.8 % strongly agree that most households possess more than 5 electronic gadgets. Twenty-six (26) 32% also agree; this combines to give 93.8 % of participants who supports the statement. The electronic gadgets include things like radios, televisions, computers, cell phones and heaters amongst others. While they possess these e-gadgets, 85.8 % of the respondents strongly agree that people are not aware that every electronic product they own will be e-waste at one point in time. The statistics presented above in Figure 7.2 indicate that the majority of people in Harare are unaware that their electronic goods are potential e-wastes in waiting. Study findings also revealed that there is a positive correlation between the population numbers and the quantities of e-waste generated in urban centres. Developing countries need an integrated electronic waste control policy since there are no measures in place to educate customers on how to deal with obsolete electronic equipment, such as mobile phones, since they are not aware of the hazards this pose (Meltzer, 2014).

### 7.4 E-WASTE GOODS TRADERS AND CUSTOMERS RELATIONSHIP.

To establish the extent and level of understanding of e-waste management in Harare, Zimbabwe it was also critical to find out the relationship between sellers and producers of electrical and electronic goods, and the consumers of such commodities' understanding of e-waste management comes from knowledge and understanding of the concept e-waste. Figure 7.3 below mirrors the kind of relationship that exists between these players. This was looked at from an e-waste management point of view as the main issue to the effective management of e-waste.

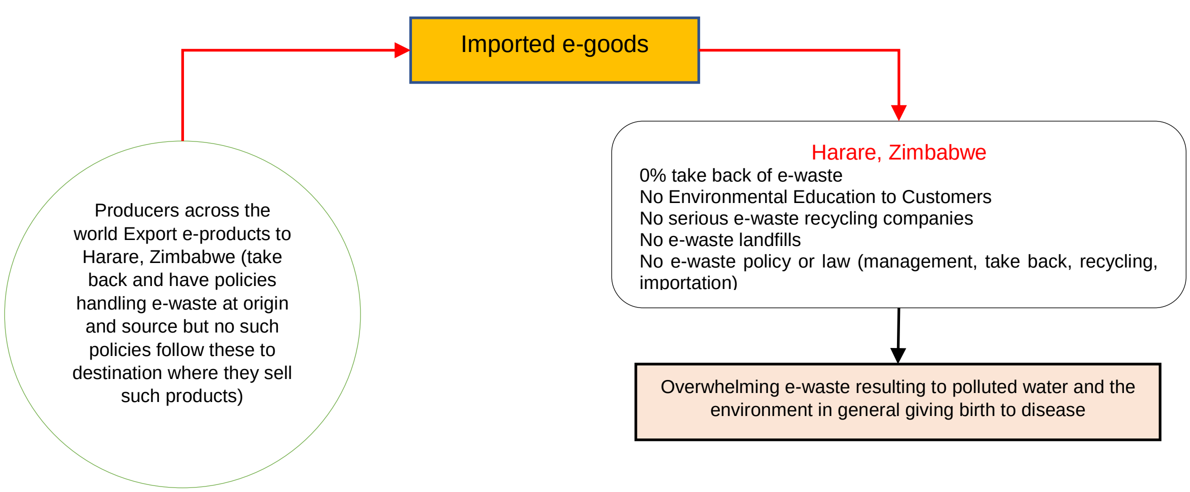
Figure 7.3: Electronic Goods Traders and Relations with Customers




Sources: Primary Data, (2019).

The responses shown in Figure 7.3 above reveal the relationships between electronic good sellers and their clientele. Study findings indicate that electronic goods traders do not educate their customers about the dangers of e-waste. This only makes business sense because should they do so, then they could put themselves out of business when people become environmentally conscious. It is also possible that the sellers of electrical and electronic goods are also unaware of the dangers of what they sell. Moreover, there is no law in Harare, Zimbabwe compelling them to give such advice. This goes along with the fact that the broader picture is that there are limited companies in Harare producing electrical and electronic goods. For this reason, the majority of the electrical and electronic products are imported. This importation of electrical and electronic goods is not controlled by any law. As matters stand, most of the goods imported are of poor quality and second-hand.  This means they will be expiring soon and since there is no tracking of such products, customers simply use them oblivious of the e-waste management options that should be taken thereafter. Interviews with experts from environmental institutions in Harare pointed to bulky importation of electrical and electronic products to and by a people whose management of obsolete e-waste is marred with a problem that it's close to none. This is diagrammatically explained in Figure 7.4 below.

Figure 7.4: Effects of Electronic Products Importation on Harare




Source: Field survey, (2019).

Eighty (80%) of the respondents indicated that customers buy goods and when they become obsolete there are no take-back policies in place. In Harare, Zimbabwe there are no large electrical and electronics producing companies. The city's dwellers rely on the importation of most electrical and electronic products. Despite this, little to no capacity to manage e-waste was indicated during interviews.

The importation of electrical and electronic products voids the take-back concept as there are no locally based recycling companies to take back the obsolete electrical and electronic products. Neither are there international trade laws and policies to address such environmental issues. While this is the case, it is clear that e-waste is slowly but surely overwhelming Harare and has a multiplicity of illegal dumps mounting. Research on environmental management also collaborates that both e-waste together with other forms of household solid waste are receiving little attention from the responsible authorities.

Advertisements only encourage customers to buy particular electrical and electronic goods with no hint on the waste and pollution part of the product when they become obsolete. The few companies in Harare, Zimbabwe that produce electrical and electronic products do not have clear environmental policies or e-waste management plans, as they rely on the municipality for e-waste management direction. This is further complicated by increased imports to electrical and electronic goods, some of which will be second-hand to a city whose waste management is generally crippled by a lack of take-back policies, proper landfills and effective recycling. This creates a complex situation where customers just use electrical and electronic goods imported with no clue on their future impact on the environment. Consequently, the population of Harare ends up dumping e-waste despite posters inscribed: "NO DUMPING" at various places. This mirrors a picture of a city whose population are not environmentally educated and know little about the importance of keeping the environment clean.

## 7.5 ACTIVITIES WHICH EXPOSE PEOPLE TO E-WASTE HEALTH HAZARDS

The pictures presented on Plate 7-2 below depict some of the daily activities which predispose the people of Harare to the dangers of e-waste health hazards. These aspects vary from using water for laundry and the agricultural watering of edible vegetables.

Plate 7-2: People Risking Heavy Metals in Mukuvisi River

| *An individual washing clothes along the Mukuvisi River in Harare* | *Clothes drying in the sun* |
| --- | --- |
|  |  |

Sources: Field survey, (2019).

Field findings indicate that due to water shortages, residents in Harare have resorted to using water from the Mukuvisi River for the washing of blankets and clothing. This is despite the river being heavily polluted and posing health hazards that mainly come from heavy metals such as lead, cadmium, zinc and others. The heavy metals from the water are likely then absorbed by the skin, especially when blankets were washed in heavy metal concentrated water from the Mukuvisi River. The result is that those who come in contact with the water, become exposed to heavy metal related health problems. This was observed in Glen Norah close to the Mbudzi roundabout and downstream close to the Mukuvisi Bridge.

Despite using the polluted water for laundry, it was also observed that the residents also use the water for watering vegetables in gardens along the Mukuvisi River. Plate 7.3 below depicts a vegetable garden along the Mukuvisi River. Although the problem of e-waste is acknowledged, the extent of health problems among consumers of such vegetables remains unclear.

Plate 7-3: Vegetables along the Mukuvisi River

Sources: Field survey, (2019).

Riverbank cultivation has seen vegetable gardens along the Mukuvisi River being watered with the heavy metal polluted water from the river. Sadhu *et al.,* (2015) highlight that most researches show that heavy metal accumulation in many vegetables is higher than the permissible limits. Despite the no dumping sign put in various places, illegal dumping is still dominant in Harare and to enhance these gardens some of the manure used in the gardens are obtained from illegal dumps which are again sources of heavy metals.

The size of the garden (Plate 7.3) above also testifies that the vegetables are not just for single-family consumption, but possibly also for resell. There is therefore the possibility that these vegetables find their way to the market even though the edible part of the vegetable leaf has absorbed heavy metals. Heavy metals easily accumulate in the edible parts of leafy vegetable compared to grain or fruits crops, yet elevated heavy metals-uptake by vegetable affect food quality and safety of the consumers.

The notion that these heavy metals are not good for human health was also noted by Yeshida *et al.,* (2009) when he indicated that WEEE is a threat to human health. Due to the economic meltdown in Zimbabwe, people from Harare's high-density suburbs have no choice but to end up buying any vegetables irrespective of their source. It is also obvious that those who are making a living out of selling such vegetables have no time to wonder about the side effects of what they sell. It was also observed that cultivation is common at dumpsites as these are perceived to be fertile. Of note are some butter-nuts that were grown at the Golden Quarry Dumpsite. This means that people in Harare are at risk of taking heavy metals through oral ingestion. Meltzer, (2014) notes that oral ingestion is a very common pathway for the transfer of heavy metals from the environment to human bodies. This is critical as Luo *et al.,* (2010) also noted that e-waste sites are located in fields adjacent to agricultural land and plants can take up heavy metals and this will poison the consumer of such plants as an excessive amount of heavy metals in the food causes some diseases such as cardiovascular, renal, neurological and bone diseases. Some people are unknowingly being daily poisoned by heavy metal intake in Harare, Zimbabwe. This is especially as urban agriculture is fast becoming a serious practice, as people try to augment their food in an economically struggling Zimbabwe. This raises the need to heighten awareness among people as well as manage e-waste properly by bringing in proper legislation controls to regulate imports of electrical and electronic goods, as well as the management of e-waste.

The Epidemiology and Diseases Control Centre of the Harare city council could not give specific figures with regards to e-waste related illness. As they explained, unlike incidents of diseases such as cholera, dysentery, diarrhoea and others, it is difficult to tell if a certain illness was a result of heavy metals from e-waste. This prompts one to conclude that e-waste is an insidious killer. Therefore, proper e-waste management would greatly reduce the poisoning of people by heavy metals.

Observation also revealed that some religious sects that have mushroomed in Harare, Zimbabwe also use contaminated water from the Mukuvisi River for baptism. This is dangerous as people do not know that in so doing, they are exposing themselves to heavy metals through dermal absorption and oral ingestion. This means that people need to be educated on the dangers of heavy metals with regards to where they can get them and how they can reduce them. There is also a need for the city of Harare to do monitoring and surveillance of heavy metals and poisons in such areas.

Despite the limited awareness of e-waste management by the public, it was encouraging to note that certain companies and organisations in Harare, Zimbabwe dealing with electronic products seemed to be aware of the need to recycle e-waste. The evidence for such awareness among companies in electrical and electronic goods manufacturing and selling could be seen on a billboard in Avondale, an upmarket location in Harare. This is pictorially presented on Plate 7.4 below.

Plate 7-4: A roadside billboard showing e-waste management awareness.


Source: Field survey, (2019)

The picture on Plate 7.4 above depicts some Harare-based companies and organisations' awareness of the need to recycle e-waste. Notable are the entities' association with the EMA whose logo is part of the advertisement. This simply means that e-waste is not an unknown waste element in Harare, Zimbabwe. Its awareness only requires more effort, as evidence shows that companies are already in action. Despite such campaigns by companies, it must be noted that to some members of the public such billboards might just be considered meaningless advertisements that carry no meaning to them. Unless time, effort and resources are set aside for their education.

What then is needed is the extension of e-waste awareness campaigns to the rest of the population of Harare, as well as the city's waste management section. This is especially as they both still regard e-waste as a waste form with negligible effects both on the environment and human health as proved by their mixing of e-waste with the rest of other waste.

Thus, based on these findings one may inevitably conclude that awareness and management of e-waste should not be confined to companies and organisations only, but must reach the ordinary citizen who should be enlightened and come to know the importance of e-waste management and the health hazards associated with e-waste mismanagement. This extension should also go to other companies as interviews with some big companies dealing in electrical and electronic products testified that they did not have e-waste management plans in place.

Studies conducted elsewhere concluded that exposure to toxic chemicals is one of the main environmental factors contributing to the global burden of diseases (Luo *et al.,* 2010). The most common cancers resulting from these exposures are cancers of the lung, bladder, skin, mesothelium, liver, hematopoietic tissue, bone and soft connective tissue Oteng-Ababio, (2012). Due to the random character of the e-waste effect, the only effective control strategy is primary prevention that eliminates exposure, or that effectively isolates the people from carcinogenic exposure (WHO, 2013). This means that e-waste management in Harare and other like cities is critical as in so doing the people are protected from heavy metal exposure and associated health effects.

## 7.6 CHAPTER SUMMARY

The chapter sought to determine Harare's understanding of e-waste management. The general sentiments that emerged from the study are that companies and organisations are better informed of the e-waste phenomenon and understand the environmental and health implications of poor e-waste management. However, the fear of losing business has curtailed businesses that are into electronic and electrical products from making their customers aware of e-waste management. As a result, the general public has remained misinformed about e-waste management. Besides this lack of enlightenment, other factors, such as poor legislation, financial incapacitation, lack of appropriate technology, among other factors have rendered e-waste management futile. Evidence from the researcher's observation confirmed the presence of multiple undesignated e-waste dumpsites in Harare. This poses both environmental and health hazard challenges. From these findings, one may conclude that there is a need to heighten public e-waste management awareness efforts. The next chapter looks at the development of a model for effective electronic waste management for Harare.

# Chapter 8

## MODEL FOR EFFECTIVE E-WASTE MANAGEMENT FOR HARARE

### 8.0 INTRODUCTION

The preceding chapter determined the population of Harare's understanding of the phenomenon of electronic waste management. This chapter seeks to develop a model for effective e-waste management for cities like Harare in developing countries, to bring about a holistic appreciation of the critical elements or vital considerations for effective e-waste management. Initially, there was the need to highlight some of the major impediments to effective e-waste management. These specifically included the haphazard nature of operations, inadequate vehicles, financial incapacitation, and lack of e-waste management legislation, poor research output, and limited public awareness. These act as drawbacks to proper e-waste management because authorities do not have enough technical and financial resources to fund research on proper e-waste management systems. There is also limited public information on e-waste management and the little activity on e-waste is scattered among informal recyclers. This further complicates efforts to do proper e-waste management. After a critical review of these highlighted challenges, the following were identified as the vital considerations for effective e-waste management: precise regulatory and policy framework, research, innovation and development, education and training, systematic operations and stakeholder involvement. This chapter starts by looking at the major impediments in e-waste management in Harare, Zimbabwe.

### 8.1 MAJOR IMPEDIMENTS IN E-WASTE MANAGEMENT IN HARARE

E-waste management in cities of developing countries is still marred by a myriad of impediments (Balde *et al,* 2017; Mandevere, 2016; ILO, 2019). Findings from this study reveal that e-waste management in Harare, Zimbabwe is still faced with several challenges that compromise the effectiveness of the available e-waste management strategies. Generally, some of the challenges highlighted include haphazard operations, inadequate vehicles, limited recycling technology, insufficient capacitation, poor research output, limited public awareness and absence of e-waste management legislation. However, before the discussion of these challenges, there is a need to understand the capacity of the City of Harare to treat and dispose of e-waste.

### 8.1.1 Harare's capacity to treat and dispose of e-waste

Another chi-square test was done to establish the existence and strength of a relationship between the idea that the Harare City Council cannot treat and dispose of e-waste on one hand, and the fact that e-waste is mixed with other forms of waste when disposed of, on the other. The results confirmed that there is a relationship between the two opinions. These results confirmed the Harare City Council's incapacity to manage e-waste effectively.

Table 8-1: City of Harare's Capacity to Treat and Dispose of e-waste

| The Harare City Council cannot treat and dispose of e-waste * Recycling of e-waste is not common in Harare Cross tabulation | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | Recycling of e-waste is not common in Harare | | | | Total |
| | | | Disagree | Neutral | Agree | Strongly Agree | |
| The Harare Local Authority cannot treat and dispose of e-waste | Strongly Disagree | Count | 0 | 0 | 0 | 3 | 3 |
| | | Expected Count | .1 | .1 | .8 | 2.0 | 3.0 |
| | Disagree | Count | 4 | 0 | 2 | 0 | 6 |
| | | Expected Count | .2 | .2 | 1.6 | 3.9 | 6.0 |
| | Neutral | Count | 0 | 1 | 5 | 1 | 7 |
| | | Expected Count | .2 | .2 | 1.9 | 4.6 | 7.0 |
| | Agree | Count | 0 | 2 | 14 | 7 | 23 |
| | | Expected Count | .8 | .8 | 6.3 | 15.1 | 23.0 |
| | Strongly Agree | Count | 0 | 1 | 10 | 64 | 75 |
| | | Expected Count | 2.6 | 2.6 | 20.4 | 49.3 | 75.0 |
| Total | | Count | 4 | 4 | 31 | 75 | 114 |
| | | Expected Count | 4.0 | 4.0 | 31.0 | 75.0 | 114.0 |

Source: Field survey, (2019).

The table above (Table 8.1) present the state of e-waste management in the city of Harare. The general sentiments from the respondents as presented on the table above portrays inadequate e-waste management efforts. This then leads to the discussion of factors said to be behind the failure of the City Council to effectively manage e-waste in Harare. Such an understanding of the challenges of e-waste management was necessary for the establishment of the vital considerations for effective e-waste management in Harare and similar cities of the developing countries.

### 8.1.2 Haphazard operations

A major impediment cited by most respondents was the haphazard nature in which e-waste management operations are conducted in Harare, Zimbabwe. Sixty per cent of the respondents were of the view that e-waste management operations were not systematic. In essence, many respondents cited the unclear regulatory frameworks, imprecise policies, irregular operating procedures and discordant systems, as weaknesses that restrict effective e-waste management. The general sentiments expressed with regards to the environmental regulatory framework for Zimbabwe was captured in the voices presented below:

> *“I don’t think there are policies in place to assist the responsible authorities to carry out their mandate effectively, nor effective statutes to guide e-waste management practitioners. There seem to be no structures nor proper systems in place to evaluate efforts of these entities tasked to deal with e-waste management”*
>
> *Member of the public.*
>
> *"There seems to be poor policy coordination in e-waste management. E-waste is not regulated separately; it is just regarded as wastes"*
>
> *Harare City Council worker*
>
> *“The current environmental Act only talks of hazardous substances and does not single out electrical and electronic waste as a stand-alone form of waste”*
>
> *ZEMA official*
>
> *“All the available Acts relating to public health such as the Water Act, Public Health Act, EMA and others are silent about electronic waste. If ever they talk of e-waste it will be indirect”*
>
> *Ministry of Environment Official*

These particular respondents’ views reveal that there are no clear and relevant policies on e-waste management. A closer look at the statements reveals that without proper guiding frameworks, e-waste management will not be effective in Harare, Zimbabwe. Seemingly, if the state of affairs remains unchallenged, then the scourge of e-waste will continue to grow unabated in Harare. The major talking point is on the effectiveness of the current environmental laws governing the management of e-waste in Harare, Zimbabwe. One would look at the link between the specific laws at the local authority, national and international levels. In addition, the concerned stakeholders must be fully aware of the legislative pieces to ensure effective enforcement.

The Zimbabwe Environmental Management Act (Chapter *20:27)* is silent about e-waste and only mentions hazardous substances which in this case are supposedly meant to include e-waste. The general absence of e-waste legislation in Zimbabwe has hampered e-waste management efforts. Having indicated that e-waste is one of the fastest-growing forms of waste, the law of the country needs to define a position with regards to such a form of waste rather than just generalising the problem. More so, when the constitution gives people the right to a clean environment.

During the survey, the majority of respondents of some over 60% strongly agreed that e-waste management has no specific law governing it, thus indicating a critical gap on the legislative part. The findings were backed up by Gweme, *et al.,* (2016), who indicated that Zimbabwe has no policy or legislation on e-waste except the Environmental Management Act (Chapter 20:27) which does not talk of e-waste or even mention it directly. The EMA Act simply prohibits the discharge of hazardous waste into the environment. The situation is also exacerbated by a complete absence of e-waste control or management options by other pieces of legislation such as the Public Health Act (Chapter 15:09), Urban Councils Act 29:15) and the Water Act (Chapter 20:22). These acts just mention keeping the environment free of pollution but are not specific on e-waste. To worsen matters, the institutions administering these Acts have limited or no capability to ensure any e-waste pollution control.

The importation of short lifespan electrical and electronic goods from countries like China, and second-hand electrical and electronic goods from all over the globe, complicates the management of e-waste in Harare, Zimbabwe. Study findings indicated that in general the of people in Harare own old and cheap Chinese electronic products. These products quickly turn to waste, adding to the burden of the already incapacitated Harare municipality. Such increased e-waste streams have also stimulated the rise of undesignated e-waste dumps in the city of Harare. Some of the respondents even called for legislation that controls the importation of electronic goods, as this will go a long way in reducing the effects of e-waste. The generation of e-waste in Harare exceeds and out-paces the collection, disposal and management of e-waste. Thus, there is a need to create anti-dumping laws which would be enforceable.

### 8.1.3 Inadequate vehicles

Findings indicate that the Harare City Council has the equivalent of one (1) vehicle per ward, as they have only 47 vehicles to collect waste in the 46 wards of Harare (Mandevere, 2016). These are for the collection of waste in general and little if any is set aside for e-waste. This further emphasises the notion that e-waste is treated just like any other form of waste in Harare, Zimbabwe. There is no special treatment for e-waste despite it being a source of dangerous pollutants. Interviews with experts in the Harare waste management department confirmed that currently, Harare has no waste separation strategy.

The breakdown of waste collection vehicles is very frequent and service is erratic due to financial handicaps. This means the collection of waste, e-waste included, is erratic thus giving birth to roadside dumps. Studies conducted to date indicate that the rise of undesignated e-waste dumping leads to environmental pollution as well as contamination of water sources, posing health hazards (WHO, 2013; Mandevere, 2016; Edokpolo, *et al.,* 2014; Aliyu, 2011). This is against a background that according to ZINWA, Harare has 1 000 boreholes owned privately and publicly and the monitoring of these boreholes for heavy metals is not done regularly as authorities' site financial and technical resources as the absolute drawback. Exposure to heavy metals is also common in unregistered boreholes as well as shallow wells in the mushrooming illegal and subserviced settlements in Harare.

Findings from the study indicate that the Harare City Waste Management Department is currently relying on very limited resources to manage its waste. The general sentiments expressed by respondents is that this complicates the management of e-waste as the city only has limited vehicles to move waste to designated points. Below is Table 8.2 showing the number of vehicles currently in use in the management of waste in general in Harare, Zimbabwe.

Table 8-2: Harare waste management vehicles

| TYPE OF VEHICLES | NUMBER |
|---|---|
| Compactors | 47 |
| Tractors | 12 |
| Tippers | 6 |
| Skip trucks | 6 |
| Front-end loader | 2 |
| Landfill compactor | 1 |
| Dozer | 1 |

Source: Harare City Council, (2016).

Table 8.2 above highlights how inadequate vehicles for waste management are in Harare. Evidence from the study findings indicates that the greater chunk of these vehicles is not operational. The difficulties of servicing grounded machinery have compounded e-waste management efforts. The presented statistics show that waste management is expensive and significantly withdraws from the municipal budgets, especially of those in developing countries. This confirms Maphosa and Maphosa (2020)'s argument that more than 20% of the municipality budget goes to waste management. The cost and the complexity of managing e-waste have posed major challenges for e-waste management in Harare, Zimbabwe.

### 8.1.4 Financial Incapacitation

The problems identified include among others, financial incapacitation as the Harare municipality has an inadequate financial muscle to undertake e-waste recycling. Financial challenges have meant that responsible authorities lack the finances to hire or train experts in the field of e-waste management and purchase appropriate technology for e-waste management.

Respondents also highlighted that waste in Harare is treated the same way due to a lack of appropriate technology to deal with e-waste. From the findings, the city of Harare does not have the appropriate technology to recycle e-waste. Interviews with the city officials showed that Harare does not have among its 300 registered recyclers a company specializing in e-waste recycling. The only known recyclers of such are scavengers at the Pomona and Golden Quarry dumpsites who also are using primitive and rudimental recycling methods.

### 8.1.5 Poor research output

The study findings also found that there is limited research on e-waste management. Respondents highlighted that there is a need to focus more on ways to solve the problem of e-waste. An environmental officer, specialising in waste management from ZEMA and officials from the Ministry of Environment, Water and Climate in the field of e-waste management complained that current e-waste management methods being tried are not suitable to cities in developing countries. This is because they were tailor-made for developed economies that have adequate financial as well as the technical capability and expertise necessary to undertake proper e-waste management.

### 8.1.6 Limited public awareness

There seems to be a general lack of e-waste management awareness and appreciation within Harare. Study findings revealed that although respondents seemed aware of the general definition of e-waste, they are not well-informed of the dangers of e-waste mismanagement. A lack of appreciation of the dangers posed by e-waste has led to practices that pre-disposes them to e-waste poisoning. Such limited know-how on e-waste de-campaigns efforts to manage e-waste.

Thus, one may conclude that several factors have helped generate perfect conditions for incubating the e-waste problem. The result of which has given rise to undesignated dumpsites in Harare. Such a scenario poses both environmental and health hazards. The next section focuses on important considerations for effective e-waste management.

## 8.2 VITAL CONSIDERATIONS FOR EFFECTIVE E-WASTE MANAGEMENT

This study isolated diverse strategies and mechanisms for effective e-waste management. Research findings indicate that cities in developing countries require viable strategies for effective e-waste management. In this study, strategies are viewed as the critical elements or vital considerations for effective e-waste management. In this regard, some elements were isolated as critical for the effective management of e-waste. These are precise regulatory frameworks, research, education and training, systematic operations, stakeholder involvement, the usual waste management reducing options (recycle, reduce, rethink, avoid), as well as other aspects. These elements are discussed in greater detail below.

### 8.2.1 Precise regulatory and policy frameworks

Precise regulatory frameworks were isolated as important in issues to do with e-waste management. Regulatory frameworks help in offering guidance to operations and safeguarding the interest of interested parties. Most respondents identified policies, codes of practice and guiding rules and regulations as critical in the development of best practices in e-waste management.

From the same perspectives, research findings indicate that effective policy frameworks are essential in developing a model for effective e-waste management. The policy framework in this study entails public documents with statements that guide institutional operations including goals and aspirations on how they should be achieved. Given this understanding, it was intriguing to note that 73% of 300 respondents reiterated that an absence of an effective policy framework negatively affected the general implementation of effective e-waste management in Harare, Zimbabwe.

Based on the general sentiments expressed by respondents, one can argue that a good and precise regulatory framework leads to effective e-waste management. As such, statues serve as guiding frameworks for effective e-waste management. However, in the dynamic environment, there is a need to timeously and regularly reflect on the policy framework changes. Therefore, one may argue that policy issues should not be taken lightly and that policymaking, review and implementation should involve different stakeholders and those in authority (Easton's 1965 Political Systems Model). However, Bourdier's 1984 Distinction Concept argues that the taste of those in power and the elite tends to override those of lower classes in society. This means that policy can be dictated and, in the process, it can negatively impact e-waste management efforts in Harare.

Study findings also indicated that Zimbabwe does not have specific electrical, electronic products and e-waste anti-dumping laws. Current regulatory and policy framework do not specify e-waste management as an issue of focus. An official from EMA highlighted that punitive measures for waste dumping are not restrictive with the fine pegged very low. Law enforcement in Zimbabwe is also erratic resulting in e-waste dumping occurring everywhere. The increased rate of old machinery and cheap electronic products has also increased the rate of e-waste problems. Thus, respondents highlighted that there is a need to regularise importation laws to monitor and regulate the importation of such to curb the problem of e-waste in Harare, Zimbabwe.

Because of the above, the model presented below (Figure 8.1) cannot operate in a vacuum. Therefore, the government's involvement is critical in issues involving the national legal framework. Seemingly, there are individuals and private companies which are into e-waste recycling, but the ideal situation is that they should be guided by the statutes of the country for effective e-waste management. Concisely put, only precise regulatory and policy frameworks can help to bring about effective e-waste management in Harare, Zimbabwe.

### 8.2.2 Research, Innovation and Development

Findings isolated research and development as another strategy and mechanism that can assist in developing a model for effective e-waste management. In this study, research entails a systematic scientific enquiry to establish new facts or validate those that already exist. All things being equal, research should lead to a result in the production of new knowledge, systems, operations, processes or facts translating to transformation as well as improved standards of life (Kariuki and Misaro, 2013). Research and development are, therefore, not treated separately in this study, given their symbiosis.

This study provides evidence on what has been done so far about e-waste management in the Zimbabwean context. Most respondents shared similar sentiments that research output is on the increase and should positively impact the progress on efforts to manage e-waste. During an interview with an official from the Ministry of Environment, this researcher was informed that efforts to reduce e-waste were lagging due to a lack of new ideas to develop new strategies for e-waste management.

Studies conducted to date indicate that for sectors that embark on extensive research on problems existing in their areas of jurisdiction, solutions come quickly. Respondents from EMA, Ministry of Environment and Ministry of Health and Child Welfare revealed that there is a need to research e-waste to develop new initiatives rather than just taking western ideas that are not tailor-made for the Zimbabwean environment. The general sentiments expressed highlighted that research is a pillar of progress, since it informs concerned stakeholders on what needs to be done and who needs to do it, how and why. Kariuki and Misaro, (2013), observed that this research approach has brought about ideal ideas and technology. Therefore, the general picture portrayed by their views is that research serves as a strategy and mechanism to identify and proffer solutions to problems affecting the operations of e-waste management in Harare, Zimbabwe and beyond. Research has the potential to provide solutions.

In summary, there is a need to intensify research to innovate and develop new ways for managing e-waste. It can be argued that in the absence of research, it would be difficult to effectively manage e-waste in Harare, Zimbabwe.

### 8.2.3 Education and Training

Research findings identified education and training as another strategy and mechanism for developing best practices in e-waste management. Education and training in this study, are viewed as means of imparting knowledge and skills on e-waste related issues. The two are used synonymously for the enlightenment of individuals about what should be known with regards to e-waste related issues. Most respondents regarded education and training as influential in facilitating effective e-waste management strategies. They used terms such as knowledge acquisition, equipping with skills, enlightening and the provision of relevant information, teaching, learning, programs and schooling in most of their responses. This revealed the significance of the strategy in availing the basic information about effective e-waste management for Harare, Zimbabwe.

Hundred per cent (100%) of officials interviewed viewed education and training as an effective means of ensuring effective e-waste management. Some respondents also argued that ignorance is a major drawback to most developmental plans. Therefore, they suggested that ignorance eradication through related knowledge edifying programs is critical if the public and responsible authorities care to comprehend and appreciate the significance of effectively managing e-waste. Most respondents also perceived knowledge and skills acquisition as influential to the provision of effective management services as well as effective implementation of effective strategies. They also regarded knowledge as an effective weapon to fight management problems. However, research findings indicate that Harare, Zimbabwe needs extensive education programs to both equip responsible authorities in e-waste management with the right knowledge and skills, as well as increase public awareness on e-waste related issues to effectively manage e-waste. These findings are in tandem with the notion that education and training equip employees with expected skills and standards to deliver quality services. Seemingly, the acquisition of relevant knowledge and skills in e-waste management can translate to the development of effective ways to manage e-waste.

Awareness programs were also perceived as another means to help individuals understand the importance of understanding e-waste management issues. In this study awareness programs are regarded as method, tactics and techniques of making individuals conscious of the concept of e-waste management and the benefits of effectively managing e-waste. Findings indicate that awareness programs and campaigns also enlighten individuals on unclear issues to do with e-waste management.

Respondents aired these sentiments after arguing that only a small segment of the entire Zimbabwean population is knowledgeable about e-waste related issues such as environmental and health hazards posed by its mismanagement. Seemingly, awareness campaigns and programs are an integral part of the informative methods to help people comprehend the benefits of effective e-waste management.

These findings indicate that the generality of the respondents viewed education as the lifeblood of knowledge and skills transfer. While there are diverse means of educating individuals about a certain phenomenon, awareness campaigns and programs are seemingly short-lived, leaving recipients with limited information. These findings suggest that knowledge and skills impartation are instrumental to the development of effective ways to manage not only waste, but e-waste as well.

Coupled with the given evidence, these findings are an indication that knowledge and skills are critical pillars for developing some effective ways to manage e-waste in cities of developing countries like Harare, Zimbabwe and several other like cities.

However, some education and training models offered elsewhere may not be compatible with the expectations of the local culture. In such a scenario, research should be conducted before adopting and adapting any education and training models from other countries. Therefore, much reasoning is expected in such situations to avoid disappointments. In the same perspective, reasoning helps to determine a course of action based on the expected outcomes and output. These findings suggest that the theory of reasoned action has an upper hand in deciding on an appropriate model to adopt. However, reasoning should also include further investigations to reveal the extent to which a model can or cannot apply to a certain context. Education and training enlighten individuals about how to do certain things properly which also translates to effective e-waste management.

### 8.2.4 Systematic Operations

Respondents regarded systematic operations as another strategy and mechanism to effectively manage e-waste. Research findings indicate that e-waste management in Harare, Zimbabwe require clear processes and systems for informed functionality as too many authorities are tasked with e-waste management leading to conflict and duplication of work.

Contrariwise, conflict of interest usually arises between these different parties, which sequentially complicates the entire e-waste management process and successively impinge on progress. Such conflicts can therefore be explained using Social Conflict Theories with its ideology of power struggle. Indeed, conflicts become dictates to social change which is always subjective. It can also be argued that, for as long as there are differences, only limited advancement can be realised in e-waste management initiatives. A compromise is required by either party involved to minimise conflict and lead to the development of an effective e-waste management model. Thus, there is a need for a collaborative effort among those authorities tasked with e-waste management in Harare, Zimbabwe.

These sentiments suggest that collaboration brings about new ideas in dealing with e-waste management. It can also be argued that for the success of collaborative work, there is a need for a shared vision and objectivity in the operations of e-waste management. However, the smooth flow of the operations may also be affected by the policies that govern the operation of various sectors that may share a common interest with the Ministry of Environment. In Zimbabwe, the Ministry of Environment and Climate change, Ministry of Health and Child Welfare, EMA and others all have a stake in e-waste management. Thus, respondents argued that to have systematic operations in place, there is a need to streamline stakeholders tasked with the powers to oversee e-waste management. In Zimbabwe, several stakeholders such as EMA, City and Town councils among others, all have a say in e-waste management. This led to bickering back and forth, jabs when trying to develop and implement effective e-waste management strategies. Thus, for successful and effective e-waste management there is a need to streamline stakeholders so that they have defined authority and the judicial powers to oversee e-waste management.

### 8.2.5 Stakeholder involvement

Study findings indicate that for effective e-waste management there is a need for stakeholder involvement. Findings indicate that about 300 licenses have been offered to individual recyclers in Harare. However, evidence indicates that neither financial nor expertise development is extended to these independent recyclers. This then has a telling effect on their efficiency and effectiveness in e-waste management. Thus, one strategy for effective e-waste management is to allow stakeholder involvement to ensure that they know the value of e-waste recycling and the benefits attached thereto.

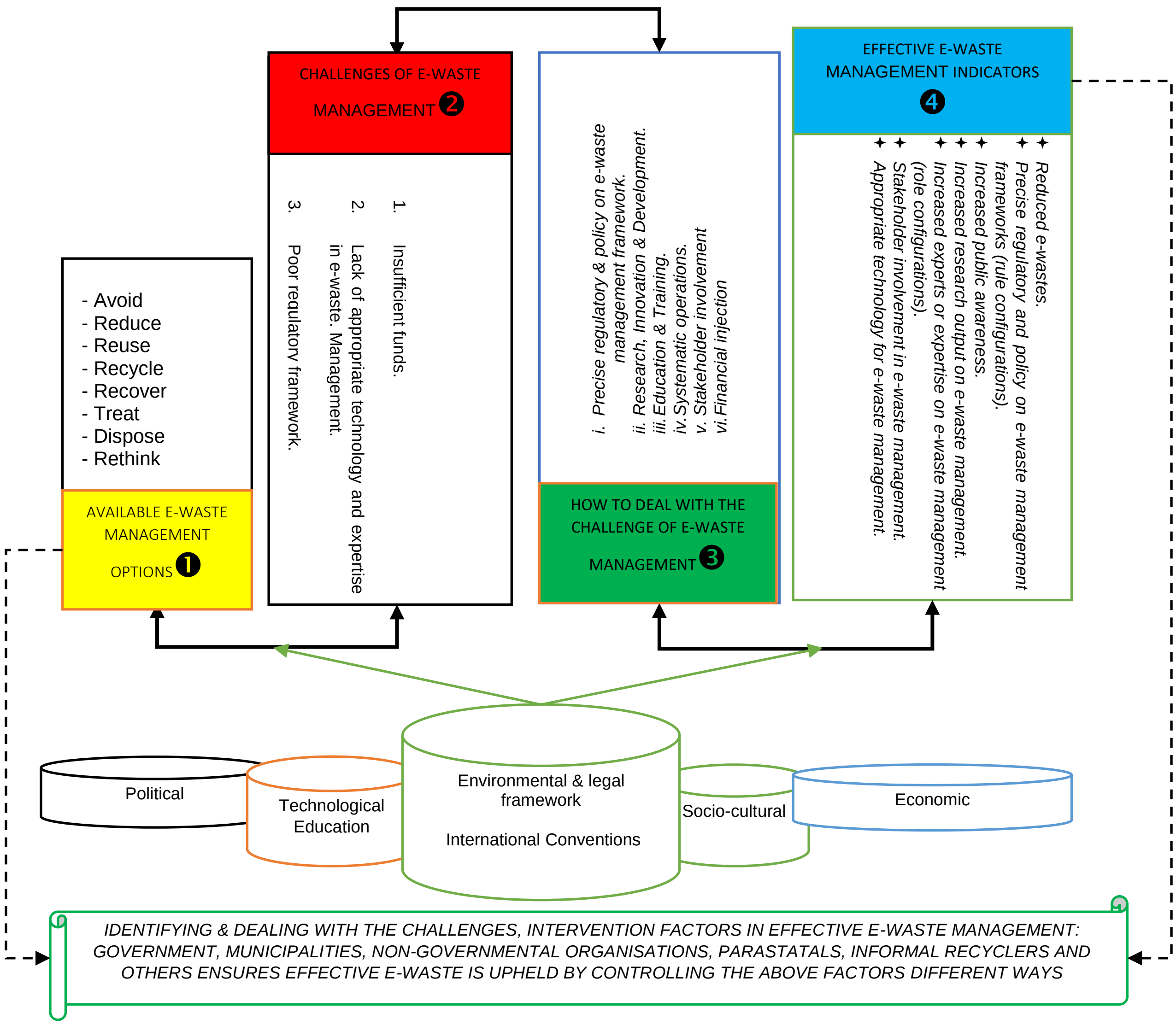
### 8.3 POSSIBLE ENCUMBRANCES TO EFFECTIVE E-WASTE MANAGEMENT

While people can come up with excellent strategies and mechanisms for effective e-waste management, some possible interferences can limit the achievement of the intended outcomes. These encumbrances can also be viewed as interferences, mediations, interpolations or unexpected occurrences that can affect goal achievement.

Research findings identified different environmental dynamics as major possible external factors that impinge on effective e-waste management. These dynamics include the political, economic, social and cultural, technological, environmental as well as legal factors. Meanwhile, some respondents highlighted that such issues need special attention if strategies for effective e-waste management are to thrive. The views provided by different respondents suggest that when developing a model for effective e-waste management, such factors have to be considered or controlled otherwise resources may be put to waste. Effective control of diverse limiting forces results in a model for effective e-waste management (MEEW).

A model for effective e-waste management in Harare, Zimbabwe has various aspects which enrich effective e-waste management. Similarly, it provides a mirror of the possible or assumed challenges the management of e-waste would likely face. With the model being in place and implemented, there needs to be a mirror to check for the success and failures of the e-waste management systems. This way, the whole process of e-waste management then happens in a context where politics, technology, environmental education environmental legislation, electrical and electronic products import-export legislation, socio-cultural beliefs and the economics of Harare, Zimbabwe interact on a level field. Other players, such as international conventions on environmental management, can also participate. Diagrammatically, Figure 8.1 below is what a feasible model should look like.

Figure 8.1: Model for effective e-waste management




Source: Survey, 2020

## 8.4 MODEL FOR EFFECTIVE E-WASTE MANAGEMENT (MEEW)

Figure 8.1 above shows a model for effective e-waste management applicable in cities of developing countries like Harare of Zimbabwe. A myriad of challenges was identified as limitations to the effective management of e-waste. Therefore, study respondents proffered various strategies and mechanism to overcome the identified problems and a model conducive for effective e-waste management was developed.

Meanwhile, the model Figure 8.1 above project an effective e-waste management model and is realistic and practical for Harare, Zimbabwe. Therefore, the developed model for effective e-waste management (Figure 8.1 above) is feasible for Harare, Zimbabwe as the e-waste problem is manifesting everywhere. Below is a bird's eye view of the highlighted intervening factors to the effective management of e-waste in Harare, Zimbabwe.

The political environment affects operations in e-waste management. The government has regulatory frameworks and policies which may impact all sectors depending on its level of facilitation or intrusion to related operations. In short, environmental laws, health laws, laws to do with land and water, electrical and electronic products importation and exportation laws among a host of others, have both direct and indirect negative and positive effects on e-waste management. In the same vein, the central government should also recognize the significance of managing e-waste. The identified strategies and mechanism would be meaningless if government policies interfere with the sectorial operations. Government has to offer political goodwill to those involved in e-waste management be they municipalities and independent players. Therefore, the model for effective e-waste management may not be viable in a country that has e-waste management unsupportive regulatory frameworks and policies impinging on a host of other related processes specifically e-waste management.

The political situation also dictates the ability of the government to access financial assistance or expertise from across the borders. International relations and goodwill can only be enjoyed if the political atmosphere of a country is conducive. Currently, the Zimbabwean government has launched initiatives to re-engage the international community to do business in Zimbabwe. The country has been under economic isolation and as such is failing to bring about critical players conversant with issues of waste management. Until about two decades ago, Harare used to rely on donor funding to manage its waste. The initiative to re-engage the international community might bring the much-needed funding, expertise and technology diffusion leading to the acquisition of appropriate technologies for e-waste management. A good political environment equals a favourable ground for the attraction of capital to undertake effective e-waste management programmes.

When the economic environment is not vibrant, the way e-waste management practices are conducted are also negatively affected translating into poor e-waste management. This is especially as economic environments dictate the ability of the responsible authorities to purchase appropriate technologies, train or hire experts in e-waste management, offer to fund, involve private stakeholders in e-waste management, offer motivating salaries to council workers/employees in the e-waste management section, carry awareness campaigns among other such activities.

Another factor that needs monitoring and control to achieve intended objectives include the beliefs, interests and attitudes of the public. Thus, the social-cultural environment can negatively affect the goal of effective e-waste management, making the identified strategies and mechanisms worthless. Therefore, there is a need to re-orient the public on the benefits of e-waste management and the environmental and health costs associated with e-waste mismanagement or its mismanagement. The study findings identified that there is limited public awareness on e-waste management related issues, especially those surrounding e-waste disposal, recycling, and other aspects. Thus, there is a need to change the current public disposition with regards to how e-waste management is practised. A positive e-waste management attitude would positively complement e-waste management efforts. This could be possible through awareness campaigns through different media such as social media platforms, radio, televisions, the internet and so forth.

By and large, legal factors are critical in determining the success or failure of e-waste management initiatives. Legal factors help in maintaining sanity, offering guidance in operations and is key in prohibiting illegal e-waste dumping. Key factors that need to be controlled under such an environment include: issues to do with regulating the importation of electrical and electronic products and e-waste, creating anti-dumping laws, offer avenues for prosecuting offenders, as well as having regulatory and policies in place.

Therefore, one can argue that the above model for effective e-waste management (Figure 8.1) can only be viable when the highlighted intervening variables are controlled or effectively monitored. If no such control and monitoring happen, it means that the management of e-waste will remain poor.

### 8.5 CHAPTER SUMMARY

Chapter eight focused on developing a model for effective e-waste management for Harare and other cities in developing countries. The chapter presented major challenges that hinder effective e-waste management. Strategies and mechanisms that would help responsible authorities to meet their goals for effective e-waste management were discussed and a model for effective e-waste management was developed. However, a couple of intervening variables were isolated as challenges to achieving the intended goals. Such intervening forces need to be controlled or regulated if responsible authorities are to achieve effective e-waste management.

# Chapter 9

## SUMMARY, CONCLUSIONS AND IMPLICATIONS

### 9.0 SUMMARY AND CONCLUSION

The study assessed waste management in Harare, Zimbabwe. A mixed methodology was employed. Critical and relevant literature was reviewed from various sources. It was found out that the levels detected for mercury, arsenic, cadmium, zinc and other heavy metals in certain areas across Harare, but mostly areas at and around dumpsites, are higher than internationally acceptable levels. This was established more on roadside dump sites as well as the official dumpsites whose levels are higher than locally and internationally acceptable standards.

- A closer look at the occurrence of these heavy metals in Harare, Zimbabwe shows that despite other contributing factors to the occurrence of heavy metals, there is gross and absolute mismanagement of e-waste in Harare, Zimbabwe as this is seen to be dumped in various undesignated localities across the city. The levels are high at and close to the official dumpsite, as well as other illegal roadside dumpsites, and this means that e-waste management is not being properly practised in Harare, Zimbabwe.

- The authorities are incapacitated and have difficulties in handling ordinary solid waste in the city, not to mention e-waste and its associated treatment and recycling complexities. Consequently, in the absence of appropriate technology and expertise on the part of the authorities to properly manage and recycle e-waste, the management of e-waste is left to scavengers. There is no record or register for e-waste recycling companies or individuals as only a list of recyclers of other forms of waste such as plastic containers and paper were availed. Further complicating this is that e-waste is fast-growing. As Schwep *et al.,* (2009), testified, e-waste generated globally is growing at a rate nearly three times faster than the overall municipal solid waste and this results in the cities being overwhelmed with the e-waste management aspect. Judging by the study findings, the city of Harare, Zimbabwe, seems to be following suit.

- The mismanagement of e-waste in Harare, Zimbabwe is greatly and largely explained by lack of funds, poor environmental education among the residents, limited expertise, shortage of appropriate technology and an upsurge in the generation of e-waste due to the rapid and swift growth of the electronic revolution and population in Harare, Zimbabwe. However, this is not unique to Harare, Zimbabwe alone. As studies by Schluep (2010), Wittsiepe *et al.,* (2015), Heeks *et al.,* (2015), Maphosa and Maphosa (2020) and ITU (2018) report, such a situation is familiar to many other cities in developing economies across the globe where the electronic revolution and Fourth Industrial Revolution are occurring.

- The environmental pollution by e-waste is a threat to public health as these deposit heavy metals into the environment which is carcinogenic and persistent. Harare has no policy or suitable, sustainable and satisfactory e-waste management services. Although legislation is available on environmental management, it is silent on e-waste as it mentions only hazardous waste. Such findings indicate that a lot of groundwork still needs to be done to ensure and guarantee an effective e-waste management regime supported by legally binding instruments which are absent to date.

- Despite environmental and public health problems pointing to poor e-waste management, it was also observed that the Harare City Council Waste Management Department is ill-equipped to do any proper e-waste management. On the other hand, research findings also showed that there is limited knowledge on e-waste among the population, especially the health and environmental hazards posed by e-waste as the waste contains heavy metals and persistent toxic substances (PTSs).

- Antagonistic tendencies in the management of waste, in general, are common in Zimbabwe. Awareness of e-waste effects on human health and the environment are still skeletal and unknown to the public. This extends even to some government departments and ministries. For instance, evidence from field findings revealed that none of these government entities has legislation attending to the management of e-waste. This makes the management of e-waste in Harare a difficult task. The ineffective management of e-waste is also shown by the ignorance of people who could not identify e-waste related diseases. The mention of cholera and typhoid is not an issue as these are known to be human killers, however, people are not aware of the silent killers that come with heavy metals in e-waste.

- It was observed that the recycling of e-waste was marred by rudimental, crude and primitive methodologies that do not only pollute the environment but also jeopardize and imperil the health of the recyclers. The people are unaware of the possible implication for their health and even the environment as most of them regard the environment as an infinite resource capable of handling all forms of waste deposited on it without being affected. Scavengers do their daily work with no Personal Protective Equipment (PPE). The indiscriminate dumping of waste without separation at the source shows that the management of e-waste is disordered. This explains why heavy metals in the soils and water bodies around Harare's main dumpsite as well as other illegal dumpsite are extreme and beyond expected local, regional and international levels.

- Lack of financial resources, political will, e-waste recycling technologies and human capital within the Harare waste management department exposes both the environment and the population to e-waste related problems and pollution. Zimbabwe's economic instability makes e-waste management difficult to manage as the country's economic situation has seen the importation of old and short life electrical products which quickly degenerate into e-waste. These further burdens an already incapacitated city of Harare and further complicate an already complicated waste management system.

## 9.1 IMPLICATIONS FOR POLICY

Policy plays a crucial role in governing and regulating the practice of e-waste management across the globe. However, study findings indicate that the city of Harare is characterised by the presence of a policy framework that lacks not only enforcement but clarity on e-waste issues. Considering the dynamism of the electrical and electronic product industry and the global focus on e-waste management systems, such policies would need to be constantly reviewed to augur well with current global trends on e-waste management. There is also a need for collaborated efforts between the electronic goods manufacturing industry, sellers of electrical and electronic products, educational and research institutions, non-governmental organisations and the government to deal with e-waste management. Collaboration is key in developing vibrant e-waste management systems.

There is a need to promote public education on hazardous substances of EEE as well as developing international, regional and national systems to advise on the levels of the hazardous substances in e-waste. There is similarly also a need to initiate sound legal and regulatory frameworks for e-waste management. This would entail coming up with laws that encourage product stewardship and extended producer responsibility and life-cycle management. In the command – and – control approach, government formulates environmental legislation, equips relevant regulating institution, provides licenses to industry and enforces the legislation to control extensive pollution (World Bank, 2000). This can be done by promoting public health education on hazardous substances of e-waste and developing from international, and regional institution a national system to advise Harare, Zimbabwe on the levels of the hazardous substances in EEE.

The results show that the management of e-waste in Harare is close to none and this is attributed to several factors. Hence the need for critical and serious insights for policymakers, residents and environmentalists on how best electronic waste can be managed to ensure that the environment is habitable and safe for human health especially considering that Harare has about 15 000 boreholes and other water sources such as Lake Chivero which are threatened by heavy metal pollution. Considering the adverse potential eco-toxicological impacts and diverse health effects of e-waste, an urgent global multilateral agreement is needed to address the management of e-waste such as handling, storage, transportation, recycling and final disposal of e-waste. The agreement should focus more on protecting the developing cities and countries like Harare of Zimbabwe as they are the most affected by the electronic revolution. Banning the importation of non-reparable EEE would also go a long way in solving e-waste problems. One of the theories is that increased regulations on electronic waste and concern over environmental harm in nature economics create an economic disincentive to remove residues before export (Kirthik *et al.,* 2017). Thus, new business opportunities such as resource recovery or precious metal mining or recovery in urban dumps become paramount.

## 9.2 IMPLICATIONS FOR PRACTICE

Findings reveal that current e-waste management practices are inadequate to deal with the growing problem of e-waste in cities of developing countries such as Harare, Zimbabwe. There is a need to revamp current initiatives and inject new thoughts into how e-waste management can be done. This section looks at some of the actions that can be taken to improve e-waste management.

The environmental management department and government entities dealing with waste management need to ensure that there is a law dealing with e-waste management as evidence is inevitably clear that the electronic revolution is growing exponentially not only in Harare, Zimbabwe but across the globe. This should ensure that electronic goods entering the borders in the name of trade and donations to bridge the digital divide are professionally monitored to reduce if not avoid dumping. It should also ensure that responsible authorities are capacitated to ensure that e-waste is well managed now when its effects are still budding than to wait until it becomes overwhelming to entities whose mandate they are failing to provide due to a runaway economy and other complications such as lack of proper technology.

There is also a need to produce a business model with appropriate technology. The informal sector needs to be engaged and a model developed in this line. A hub and spoke scenario where central processing of e-waste is critical. There is a need for conscious public awareness (creation) campaign wheel which should culminate in the promulgation of the appropriate legislation regarding proper handling of e-waste. There should also be symbiotic and synergistic solutions involving all stakeholders on the e-waste management strategy for Harare, Zimbabwe. This is a sine qua non for establishing an effective e-waste management system in Harare, Zimbabwe. It will give birth to Public-Private Partnerships (PPPs) in e-waste management, thus bringing more players in the field and enhancing effective e-waste management for Harare, Zimbabwe.

Setting up recycling and reusing commercial-industrial entities which use electronic waste as resources can be an effective strategy since the supply of the e-waste would be met by the demand. Considering that millions of absolute electronic goods are still kept in both government offices as well as individual households. For example, an e-waste processing plant can be established as e-waste is a resource available and can be in continuous supply as the electronic revolution forges on. Over 60 % of e-waste is still kept in different localities in Harare and resultantly recycling of such will go a long way in ensuring the urban mining of valuable resources from e-waste is enhanced. A command and control approach is critical if the government is to formulate environmental legislation specifically for e-waste management. Continuous monitoring of the 15 000 private and public boreholes to ensure that the levels of heavy metals in the water are within permissible limits would buttress e-waste management in Harare as it requires e-waste prevention.

## 9.3 IMPLICATIONS FOR RESEARCH

The study sought to establish the vital considerations of a model for effective e-waste management in cities of developing countries, specifically Harare, Zimbabwe. The current study concluded that current e-waste management practices are inadequate, hence it would be prudent to design novel e-waste management practices and test them under different social environments. Such studies might lead to the development of e-waste management practices that could be adapted to economic environments undergoing austerity measures (characterised by financial challenges).

It was also established that electronic waste has serious health implications to the population in general and there is no detail as to how many such cases have been reported like the normal reports surrounding cholera and typhoid. Therefore, another study can be done to establish the general picture of health issues that are caused by electronic waste, especially to those individuals who are directly into primitive e-waste recycling.

Aquatic organisms can bio-accumulate, bio-magnify or bio-transfer certain heavy metals to concentrations high enough to bring about health problems for human beings, especially by the transfer of metals through the food chain. E-waste management is not only a local problem, burning, but illegal dumping and emission from e-waste disposed of also contribute to dioxin, chlorinated organic components and heavy metals all of which are persistent and control global-warming, bio-contamination and biodiversity (Christensen, 2011). This is another area open for further studies.

It was noted during the dumpsites visits that women and children are active participants in e-waste scavenging and further studies can be undertaken to understand the health implications of informal e-waste handling and scavenging women and children especially in developing countries and their cities. Societies near the dumpsites need to be assessed in terms of safety and health issues surrounding women and children who are vulnerable in society as Greenpeace International (2008), indicated that e-waste recycling is poisoning the poor.

## 9.4 IMPLICATIONS FOR THEORY

This study derived illumination from a variety of inter-disciplinary theories such as: The Theory of Waste Management, Theory of Environmentally Responsible Behaviour, The Environmental Citizenship Theory, The Value-Belief-Norm-Theory of Environmentalism and the Diffusion of Innovation Model. Several theories were interrogated, the majority of the theories illuminating the phenomena under investigation. Hence, most of these theories could be regarded as having an explanatory validity. They applied only to the themes under study. After a critical analysis of all the `theoretical jackets', the theories emerged as overarching, with attributes that gave explanatory validity to all the major themes covered by this study.

However, the theory offers explanatory validity in terms of understanding the expectations of both companies and individuals in e-waste management initiatives (Both formal and informal). That as it may be, however, it fails to holistically illuminate the whole phenomenon. It only accounts for the behaviour of individuals and organisations in the face of motivation. It fails to account for the behaviour when people and organisations practice illegal e-waste dumping, nor provide explanations for the increased consumption of electrical and electronic products leading to increased e-waste.

Although the Expectancy Theory was identified as a close fit in illuminating the sector, the study requires an overarching theory. One that illuminates both the behaviour of organisations, individuals and that of responsible authorities in e-waste management under different conditions. This would bring a holistic understanding of the problem.

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# List of Appendices

## Appendix 1 - INTERVIEW GUIDE FOR THE KEY INFORMANTS

I kindly ask you to assist me by answering a few questions to help me find answers to my academic research. Please be assured that your responses will be strictly confidential and will be used for the sole purpose of pursuing academic interest. I am studying towards a PhD in Environmental Management with UNISA.

**Topic:** Assessment of Electronic Waste Management in Harare, Zimbabwe

- What is electronic waste management?
- What are the sources of e-waste?
- Is there a law handling e-waste management in Zimbabwe?
- Can you identify any law that deals with e-waste management?
- What electronic waste management strategies are being used in Harare? Explain?
- Do you think the current environmental law is adequately addressing e-waste management in Harare?
- Do you think Harare has an effective electronic waste management strategy in place? Please explain.
- How do you assess the electronic waste management situation in Harare?
- Is the government of Zimbabwe doing anything significant in managing electronic waste? Explain.
- What are the authorities doing to ensure proper electronic waste management?
- How has the electronic revolution affected waste management in Harare?
- Do you think a poor electronic waste management strategy has any significant effects on the environment and human health? Please explain.
- What is your opinion on the level of understanding of e-waste management among the population in Harare?

***NB:*** *Some questions will arise as respondents give answers**.***

*Thank you for giving me your valuable time and ideas.*

Appendix 2 - QUESTIONNAIRE (OPEN ENDED)

**Topic**: Assessment of Electronic Waste Management in Harare, Zimbabwe

I kindly ask you to assist me by answering a few questions to help me find answers to my academic research. Please be assured that your responses will be strictly confidential and will be used for the sole purpose of pursuing academic interest. I am studying towards a PhD in Environmental Management with UNISA.

**INSTRUCTIONS**

Complete all questions

No name or contact details should appear anywhere on the questionnaire

1. What do you understand by electronic waste?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

2. What are the dangers of e-waste?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

3. What do you think an electronic waste management law should include in Zimbabwe?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

4. Is Harare properly managing her e-waste? Please indicate your reasons

……………………………………………………………………………………………………

……………………………………………………………………………………………………

5. Other than council collection what other e-waste management options do people use?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

6. Please indicate your response using the index: [1] Strongly agree, [2] Agree, [3] Moderate, [4] Disagree and [5] Disagree strongly

| | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Residence of Harare are not aware of the dangers caused by e-waste | | | | | |
| The Law dealing with e-waste in Zimbabwe not adequate | | | | | |
| E-waste recycling is minimal in Harare | | | | | |
| The are no e-waste recycling technologies in Harare | | | | | |
| Public education on e-waste management is low | | | | | |
| E-waste is treated as any other waste by the Harare Municipality | | | | | |
| Poor e-waste management negatively affect the environment | | | | | |

7. Identify any human diseases that are caused by heavy metals

…………………………………………………………………………………………………………

…………………………………………………………………………………………………………

8. What management strategies can Harare adopt to handle their electronic waste?

…………………………………………………………………………………………………………

…………………………………………………………………………………………………………

Thank you.

Appendix 3 - QUESTIONNAIRE (CLOSED)

Topic: Assessment of Electronic Waste Management in Harare, Zimbabwe

I kindly ask you to assist me by answering a few questions to help me find answers to my academic research. Please be assured that your responses will be kept strictly confidential and will be used for the sole purpose of pursuing academic interest. I am studying towards a PhD in Environmental Management with UNISA.

**INSTRUCTIONS**

Please tick the appropriate box.

No name or contact details should appear anywhere on the questionnaire.

| Please indicate your opinion by putting a tick under relevant responses [√]. | | | | | |
|---|---|---|---|---|---|
| | **Strongly Agree** | **Agree** | **Neutral** | **Disagree** | **Strongly Disagree** |
| | **5** | **4** | **3** | **2** | **1** |
| ELECTRONIC WASTE SOURCES | | | | | |
| Sources of electronic waste are international | | | | | |
| Sources of electronic waste are local | | | | | |
| Most e-waste is not properly recycled | | | | | |
| Many households are keeping e-waste | | | | | |
| ELECTRONIC WASTE MANAGEMENT LAW | | | | | |
| Zimbabwe's current environmental laws are enough to address e-waste management | | | | | |
| Electronic waste has no law governing its management in Zimbabwe | | | | | |
| International conventions are doing very little to deal with e-waste in developing countries | | | | | |
| Zimbabwe has no law governing the importation of electronic goods | | | | | |
| ELECTRONIC WASTE DISPOSAL | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| The Harare Local Authority does not have the capacity to treat and dispose of e-waste | | | | | |
| Recycling of e-waste is not common in Harare | | | | | |
| The sellers of electronic goods have no responsibility to its management as e-waste | | | | | |
| Electronic waste is mixed with other forms of waste when disposed in Harare | | | | | |
| HEALTH HAZARDS OF ELECTRONIC WASTE | | | | | |
| Electronic waste can cause serious health and environmental problems | | | | | |
| Very few people are aware of the dangers around electronic waste in Harare | | | | | |
| It is important to educate people about health hazards caused by e-waste | | | | | |
| ELECTRONIC WASTE AND THE POPULATION | | | | | |
| Most urban households in Harare have more than 5 electronic goods | | | | | |
| People are not aware that every electronic good will be waste at one point in time | | | | | |
| Electronic waste is dominant in urban areas | | | | | |
| There is a link between population numbers and electronic waste generated | | | | | |
| ELECTRONIC GOODS AND THE MARKET | | | | | |
| Electronic goods sellers do not educate the people about the dangers of e-waste | | | | | |
| Most shops sell electronic goods | | | | | |
| There is no return back policy by producers of electrical and electronic goods | | | | | |

Thank you for participating.

Appendix 4 - OBSERVATION CHECKLIST

Topic: Assessment of Electronic Waste Management in Harare, Zimbabwe

PhD Environmental Management

OB = Observed. N/O = Not Observed, N/A = Not Applicable

| **WHAT TO LOOK OUT FOR** | **OB** | **N/O** | **N/A** | **COMMENTS** |
|---|---|---|---|---|
| 1. Clearly dumped electronic waste | | | | |
| 2. Is there separation of waste in Harare | | | | |
| 3. Is the level of e-waste understanding satisfactory in Harare | | | | |
| 4. Satellite dish receivers on houses in Harare | | | | |
| 5. Are the citizens aware of e-waste hazards | | | | |
| 6. Are there dedicated e-waste disposal sites in Harare | | | | |
| 7. Are there companies or individuals recycling e-waste | | | | |
| 8. Electronic waste legislation at Government Printers | | | | |
| 9. Signs of fire and burning of e-waste at dumpsite | | | | |
| 10. Is any e-waste dumped in water sources | | | | |
| 11.Knowledge of e-waste issues among government officials in institutions dealing with waste management | | | | |
| 12. Is there e-waste reading material in Government Libraries | | | | |
| 13. Type of e-waste equipment owned by recyclers | | | | |
| 14. Other observations | | | | |

## Appendix 5 - Soil and water Laboratory Result



**Soil**

| Customer Ref | | | | Sample 10 | Sample 11 | Sample 12 | Sample 13 | Sample 14 | Sample 15 |
|---|---|---|---|---|---|---|---|---|---|
| Type of Sample | | | | Soil | Soil | Soil | Soil | Soil | Soil |
| Sampling type/plan | | | | Grab/Random | Grab/Random | Grab/Random | Grab/Random | Grab/Random | Grab/Random |
| Lab ref number | | | | 186079 | 186080 | 186081 | 186082 | 186083 | 186084 |
| Date sample taken | | | | 16/11/2018 | 16/11/2018 | 16/11/2018 | 15/11/2018 | 16/11/2018 | 16/11/2018 |
| Date sample received | | | | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 |
| Parameters | Units | Method | Uncertainity of Measurement (±) | | | | | | |
| Arsenic | mg/kg As | *AAS Hydride Generator SOP/CM53* | TBA | 4.00 | 1.38 | 1.13 | 0.78 | 1.98 | 0.65 |
| Cadmium | mg/kg Cd | *AAS Flame SOP/CM49* | TBA | <0.01 | 0.25 | <0.01 | <0.01 | 0.75 | 0.25 |
| Cobalt | mg/kg Co | *AAS Flame SOP/CM49* | TBA | 9.75 | 5.00 | 1.75 | 1.75 | 4.25 | 2.50 |
| Iron | mg/kg Fe | *AAS Flame SOP/CM49* | TBA | 8450.00 | 906.25 | 493.75 | 218.75 | 2200.00 | 1962.50 |
| Lead | mg/kg Pb | *AAS Flame SOP/CM49* | TBA | 172.00 | 32.50 | 18.50 | 16.50 | 57.50 | 27.50 |
| Mercury (Hg) | mg/kg Hg | *AAS Hydride Generator SOP/CM53* | TBA | 0.18 | <0.01 | <0.01 | 0.05 | 0.18 | <0.01 |
| Zinc | mg/kg Zn | *AAS Flame SOP/CM49* | TBA | 130.00 | 30.00 | 45.00 | 27.25 | 562.50 | 80.00 |

*NB Conditions of sample(s). All samples were in good condition*
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**Soil**

| Customer Ref | | | | Sample 16 | Sample 17 | Sample 18 | Sample 19 | Sample 20 | Sample 21 |
|---|---|---|---|---|---|---|---|---|---|
| Type of Sample | | | | Soil | Soil | Soil | Soil | Soil | Soil |
| Sampling type/plan | | | | Grab/Random | Grab/Random | Grab/Random | Grab/Random | Grab/Random | Grab/Random |
| Lab ref number | | | | 186085 | 186086 | 186087 | 186088 | 186089 | 186090 |
| | | | | | | | | | |
| Date sample taken | | | | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 |
| Date sample received | | | | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 |
| | | | | | | | | | |
| Parameters | Units | Method | Uncertainity of Measurement (±) | | | | | | |
| | | | | | | | | | |
| Arsenic | mg/kg As | *AAS Hydride Generator SOP/CM53* | TBA | 10.00 | 0.90 | 0.78 | 0.73 | 0.45 | 5.00 |
| Cadmium | mg/kg Cd | *AAS Flame SOP/CM49* | TBA | 1.00 | <0.01 | 0.25 | <0.01 | <0.01 | <0.01 |
| Cobalt | mg/kg Co | *AAS Flame SOP/CM49* | TBA | 10.00 | 5.25 | 6.75 | 39.25 | 30.25 | 22.00 |
| Iron | mg/kg Fe | *AAS Flame SOP/CM49* | TBA | 1562.50 | 737.50 | 856.25 | 3300.00 | 6025.00 | 4312.50 |
| Lead | mg/kg Pb | *AAS Flame SOP/CM49* | TBA | 70.00 | 37.50 | 20.00 | 7.75 | 30.00 | 31.25 |
| Mercury (Hg) | mg/kg Hg | *AAS Hydride Generator SOP/CM53* | TBA | <0.01 | <0.01 | 0.03 | <0.01 | <0.01 | 1.05 |
| Zinc | mg/kg Zn | *AAS Flame SOP/CM49* | TBA | 612.50 | 45.00 | 330.00 | 13.00 | 612.50 | 63.75 |

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**Soil**

| Customer Ref | | | | Sample 22 | Sample 23 | Sample 24 | Sample 25 | Sample 26 | Sample 27 |
|---|---|---|---|---|---|---|---|---|---|
| Type of Sample | | | | Soil | Soil | Soil | Soil | Soil | Soil |
| Sampling type/plan | | | | Grab/Random | Grab/Random | Grab/Random | Grab/Random | Grab/Random | Grab/Random |
| Lab ref number | | | | 186091 | 186092 | 186093 | 186094 | 186095 | 186096 |
| Date sample taken | | | | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 |
| Date sample received | | | | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 |
| Parameters | Units | Method | Uncertainity of Measurement (±) | | | | | | |
| Arsenic | mg/kg As | *AAS Hydride Generator SOP/CM53* | TBA | 15.00 | 1,075.00 | 0.45 | 36.00 | 12.00 | 25.50 |
| Cadmium | mg/kg Cd | *AAS Flame SOP/CM49* | TBA | 0.50 | 6.25 | 1.00 | <0.01 | <0.01 | <0.01 |
| Cobalt | mg/kg Co | *AAS Flame SOP/CM49* | TBA | 10.25 | 30.00 | 12.50 | 6.00 | 9.50 | 6.75 |
| Iron | mg/kg Fe | *AAS Flame SOP/CM49* | TBA | 3790.00 | 5212.50 | 6387.50 | 9800.00 | 3125.00 | 3100.00 |
| Lead | mg/kg Pb | *AAS Flame SOP/CM49* | TBA | 255.00 | 775.00 | 6900.00 | 1012.50 | 56.25 | 100.00 |
| Mercury (Hg) | mg/kg Hg | *AAS Hydride Generator SOP/CM53* | TBA | 0.18 | 0.75 | 0.43 | 0.23 | 3.50 | 0.45 |
| Zinc | mg/kg Zn | *AAS Flame SOP/CM49* | TBA | 243.75 | 275.00 | 240.00 | 55.00 | 90.00 | 45.00 |

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Soil

| Customer Ref | | | | Sample 5 | Sample 6 | Sample 7 | Sample 8 | Sample 9 |
|---|---|---|---|---|---|---|---|---|
| Type of Sample | | | | Soil | Soil | Soil | Soil | Soil |
| Sampling type/plan | | | | Grab/Random | Grab/Random | Grab/Random | Grab/Random | Grab/Random |
| Lab ref number | | | | 186022 | 186023 | 186024 | 186025 | 186026 |
| Date sample taken | | | | 15/11/2018 | 15/11/2018 | 15/11/2018 | 15/11/2018 | 15/11/2018 |
| Date sample received | | | | 15/11/2018 | 15/11/2018 | 15/11/2018 | 15/11/2018 | 15/11/2018 |
| Parameters | Units | Method | Uncertainity of Measurement (±) | | | | | |
| Arsenic | mg/kg As | AAS Hydride Generator SOP/CM53 | TBA | 1.45 | 1.35 | 0.95 | 1.60 | 1.85 |
| Cadmium | mg/kg Cd | AAS Flame SOP/CM49 | TBA | 0.75 | 0.50 | <0.01 | <0.01 | <0.01 |
| Cobalt | mg/kg Co | AAS Flame SOP/CM49 | TBA | 7.75 | 6.25 | 0.50 | <0.01 | 0.75 |
| Iron | mg/kg Fe | AAS Flame SOP/CM49 | TBA | 5400.00 | 3200.00 | 2025.00 | 1825.00 | 1775.00 |
| Lead | mg/kg Pb | AAS Flame SOP/CM49 | TBA | 45.00 | 25.00 | 17.50 | 25.00 | 15.00 |
| Mercury (Hg) | mg/kg Hg | AAS Hydride Generator SOP/CM53 | TBA | <0.01 | <0.01 | 0.08 | 0.78 | <0.01 |
| Zinc | mg/kg Zn | AAS Flame SOP/CM49 | TBA | 112.50 | 250.00 | 40.00 | 100.00 | 50.00 |

*__NB__ Conditions of sample(s) . All samples were in good condition*
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**Soil**

| Customer Ref | | | | Sample 1 | Sample 2 | Sample 3 | Sample 4 |
|---|---|---|---|---|---|---|---|
| Type of Sample | | | | Soil | Soil | Soil | Soil |
| Sampling type/plan | | | | Grab/Random | Grab/Random | Grab/Random | Grab/Random |
| Lab ref number | | | | 186018 | 186019 | 186020 | 186021 |
| Date sample taken | | | | 15/11/2018 | 15/11/2018 | 15/11/2018 | 15/11/2018 |
| Date sample received | | | | 15/11/2018 | 15/11/2018 | 15/11/2018 | 15/11/2018 |
| **Parameters** | **Units** | **Method** | **Uncertainity of Measurement (±)** | | | | |
| Arsenic | mg/kg As | *AAS Hydride Generator SOP/CM53* | TBA | 0.25 | 18.00 | 21.00 | 21.50 |
| Cadmium | mg/kg Cd | *AAS Flame SOP/CM49* | TBA | 0.25 | 16.00 | 0.25 | 1.50 |
| Cobalt | mg/kg Co | *AAS Flame SOP/CM49* | TBA | 10.00 | 10.00 | 4.75 | 3.25 |
| Iron | mg/kg Fe | *AAS Flame SOP/CM49* | TBA | 7750.00 | 300.00 | 1525.00 | 5400.00 |
| Lead | mg/kg Pb | *AAS Flame SOP/CM49* | TBA | 25.75 | 1625.00 | 12.50 | 440.00 |
| Mercury (Hg) | mg/kg Hg | *AAS Hydride Generator SOP/CM53* | TBA | 0.75 | 1.70 | 0.15 | 3.75 |
| Zinc | mg/kg Zn | *AAS Flame SOP/CM49* | TBA | 30.00 | 637.50 | 97.50 | 262.50 |

*NB Conditions of sample(s) . All samples were in good condition*
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**Heavy Metals**

| Customer Ref | | | | | Sample 5 control | Sample 6 | Sample 7 | Sample 8 | EMA( Effluent & Solid Waste Disposal) Regulations 2007 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of Sample | | | | | River | River | River | River | | | | | |
| Sampling type/plan | | | | | Grab/Random | Grab/Random | Grab/Random | Grab/Random | | | | | |
| Lab ref number | | | | | 186014 | 186015 | 186016 | 186017 | Blue | | Green | Yellow | Red |
| | | | | | | | | | Sensitive | Normal | | | |
| Date sample taken | | | | | 15/11/2018 | 15/11/2018 | 15/11/2018 | 15/11/2018 | | | | | |
| Date sample received | | | | | 15/11/2018 | 15/11/2018 | 15/11/2018 | 15/11/2018 | | | | | |
| Parameters | Units | Method | Status | Uncertainity of Measurement (±) | | | | | | | | | |
| Arsenic | mg/l As | AAS Hydride Generator SOP/CM21 | SA | 0.0217 | <0.01 | <0.01 | <0.01 | <0.01 | ≤0.05 | ≤0.05 | ≤0.1 | ≤0.15 | ≤0.3 |
| Cadmium | mg/l Cd | AAS Flame SOP/CM22 | SA | 0.0261 | <0.01 | <0.01 | <0.01 | <0.01 | ≤0.01 | ≤0.01 | ≤0.05 | ≤0.1 | ≤0.3 |
| Copper | mg/l Cu | AAS Flame SOP/CM22 | SA | 0.0436 | <0.01 | <0.01 | <0.01 | <0.01 | ≤1.0 | ≤1.0 | ≤2.0 | <3.0 | <5.0 |
| Iron | mg/l Fe | AAS Flame SOP/CM22 | SA | 0.1252 | 0.03 | 0.53 | 0.38 | 63.00 | ≤0.3 | ≤1.0 | ≤2.0 | ≤5.0 | ≤8.0 |
| Manganese | mg/l Mn | AAS Flame SOP/CM22 | SA | 0.0051 | 0.01 | 0.02 | 0.28 | 2.80 | ≤0.1 | ≤0.1 | ≤0.3 | ≤0.4 | ≤0.5 |
| Nickel | mg/l Ni | AAS Flame SOP/CM22 | SA | 0.0436 | <0.01 | <0.01 | <0.01 | <0.01 | ≤0.3 | ≤0.3 | ≤0.6 | ≤0.9 | ≤1.5 |
| Lead | mg/l Pb | AAS Flame SOP/CM22 | SA | 0.0261 | 0.05 | 0.01 | 0.03 | 0.04 | ≤0.05 | ≤0.05 | ≤0.1 | ≤0.2 | ≤0.5 |
| Mercury (Hg) | mg/l | AAS Hydride Generator SOP/CM21 | SA | 0.0002 | <0.01 | <0.01 | <0.01 | <0.01 | ≤0.01 | ≤0.01 | ≤0.02 | ≤0.03 | ≤0.05 |
| Zinc | mg/l Zn | AAS Flame SOP/CM22 | SA | 0.0003 | <0.01 | <0.01 | <0.01 | <0.01 | ≤0.3 | ≤0.5 | ≤4.0 | ≤5.0 | ≤15.0 |

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**Heavy Metals**

| Customer Ref | | | | | Sample 1 | Sample 2 | Sample 3 | Sample 4 | EMA( Effluent & Solid Waste Disposal) Regulations 2007 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of Sample | | | | | River | River | River | River | | | | | |
| Sampling type/plan | | | | | Grab/Random | Grab/Random | Grab/Random | Grab/Random | | | | | |
| Lab ref number | | | | | 186010 | 186011 | 186012 | 186013 | Blue | | Green | Yellow | Red |
| | | | | | | | | | Sensitive | Normal | | | |
| Date sample taken | | | | | 15/11/2018 | 15/11/2018 | 15/11/2018 | 15/11/2018 | | | | | |
| Date sample received | | | | | 15/11/2018 | 15/11/2018 | 15/11/2018 | 15/11/2018 | | | | | |
| Parameters | Units | Method | Status | Uncertainity of Measurement (±) | | | | | | | | | |
| Arsenic | mg/l As | AAS Hydride Generator SOP/CM21 | SA | 0.0217 | 0.025 | 0.5 | 0.5 | <0.01 | ≤0.05 | ≤0.05 | ≤0.1 | ≤0.15 | ≤0.3 |
| Cadmium | mg/l Cd | AAS Flame SOP/CM22 | SA | 0.0261 | <0.01 | <0.01 | <0.01 | <0.01 | ≤0.01 | ≤0.01 | ≤0.05 | ≤0.1 | ≤0.3 |
| Copper | mg/l Cu | AAS Flame SOP/CM22 | SA | 0.0436 | <0.01 | <0.01 | <0.01 | <0.01 | ≤1.0 | ≤1.0 | ≤2.0 | <3.0 | <5.0 |
| Iron | mg/l Fe | AAS Flame SOP/CM22 | SA | 0.1252 | 0.48 | 0.05 | 0.11 | 0.13 | ≤0.3 | ≤1.0 | ≤2.0 | ≤5.0 | ≤8.0 |
| Manganese | mg/l Mn | AAS Flame SOP/CM22 | SA | 0.0051 | **2.20** | 0.11 | 0.06 | **0.53** | ≤0.1 | ≤0.1 | ≤0.3 | ≤0.4 | ≤0.5 |
| Nickel | mg/l Ni | AAS Flame SOP/CM22 | SA | 0.0436 | <0.01 | <0.01 | <0.01 | <0.01 | ≤0.3 | ≤0.3 | ≤0.6 | ≤0.9 | ≤1.5 |
| Lead | mg/l Pb | AAS Flame SOP/CM22 | SA | 0.0261 | 0.01 | <0.01 | 0.01 | 0.02 | ≤0.05 | ≤0.05 | ≤0.1 | ≤0.2 | ≤0.5 |
| Mercury (Hg) | mg/l | AAS Hydride Generator SOP/CM21 | SA | 0.0002 | <0.01 | <0.01 | <0.01 | <0.01 | ≤0.01 | ≤0.01 | ≤0.02 | ≤0.03 | ≤0.05 |
| Zinc | mg/l Zn | AAS Flame SOP/CM22 | SA | 0.0003 | <0.01 | <0.01 | <0.01 | <0.01 | ≤0.3 | ≤0.5 | ≤4.0 | ≤5.0 | ≤15.0 |

*NB Conditions of sample(s). All samples were in good condition*
*This test report shall not be reproduced except infull, without written approval of the laboratory.*
*For results sent by email or fax, the EMAL shall not be responsible for any changes that may be made to this test report. All EMAL official test reports have an original signature and official stamp*
*Results marked in the status column "SA" (SADCAS Accredited)"in this report are included in the SADCAS Schedule of Accreditation for this Laboratory*
*Results marked in the status column "ST(Subcontracted Test)"in this report are results obtained from a different laboratory*
*The Results relate only to items tested*

Compiled by: Name C.A Chikengu Signature ........ Date 17/12/18

Authorised by: Technical signatory; Name S. MAHUNGA Signature ........ Date 17/12/2018

ENVIRONMENTAL MANAGEMENT AGENCY
Environmental Protection Department
Analytical Services
2018 -12- 17
No. 6 Off Paulin Drive
KGVI, HARARE
Tel: 792772 Email: emalab@ema.co.zw
Website: www.ema.co.zw

**Heavy Metals**

| Customer Ref | | | | | Sample 13 | Sample 14 | Sample 15 | Sample 15A | EMA( Effluent & Solid Waste Disposal) Regulations 2007 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of Sample | | | | | River | River | River | River | | | | | |
| Sampling type/plan | | | | | Grab/Random | Grab/Random | Grab/Random | Grab/Random | | | | | |
| Lab ref number | | | | | 186075 | 186076 | 186077 | 186078 | Blue | | Green | Yellow | Red |
| | | | | | | | | | Sensitive | Normal | | | |
| Date sample taken | | | | | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 | | | | | |
| Date sample received | | | | | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 | | | | | |
| Parameters | Units | Method | Status | Uncertainity of Measurement (±) | | | | | | | | | |
| Arsenic | mg/l As | AAS Hydride Generator S( | SA | 0.0217 | <0.01 | <0.01 | <0.01 | <0.01 | ≤0.05 | ≤0.05 | ≤0.1 | ≤0.15 | ≤0.3 |
| Cadmium | mg/l Cd | AAS Flame SOP/CM22 | SA | 0.0261 | <0.01 | <0.01 | <0.01 | <0.01 | ≤0.01 | ≤0.01 | ≤0.05 | ≤0.1 | ≤0.3 |
| Copper | mg/l Cu | AAS Flame SOP/CM22 | SA | 0.0436 | <0.01 | <0.01 | <0.01 | <0.01 | ≤1.0 | ≤1.0 | ≤2.0 | <3.0 | <5.0 |
| Iron | mg/l Fe | AAS Flame SOP/CM22 | SA | 0.1252 | **3.38** | 1.12 | **4.20** | **4.89** | ≤0.3 | ≤1.0 | ≤2.0 | ≤5.0 | ≤8.0 |
| Manganese | mg/l Mn | AAS Flame SOP/CM22 | SA | 0.0051 | 0.10 | 0.08 | **2.00** | 0.21 | ≤0.1 | ≤0.1 | ≤0.3 | ≤0.4 | ≤0.5 |
| Nickel | mg/l Ni | AAS Flame SOP/CM22 | SA | 0.0436 | 0.03 | 0.12 | 0.03 | <0.01 | ≤0.3 | ≤0.3 | ≤0.6 | ≤0.9 | ≤1.5 |
| Lead | mg/l Pb | AAS Flame SOP/CM22 | SA | 0.0261 | 0.12 | 0.06 | 0.06 | 0.01 | ≤0.05 | ≤0.05 | ≤0.1 | ≤0.2 | ≤0.5 |
| Mercury (Hg) | mg/l | AAS Hydride Generator S( | SA | 0.0002 | <0.01 | <0.01 | <0.01 | <0.01 | ≤0.01 | ≤0.01 | ≤0.02 | ≤0.03 | ≤0.05 |
| Zinc | mg/l Zn | AAS Flame SOP/CM22 | SA | 0.0003 | 0.02 | <0.01 | <0.01 | 0.09 | ≤0.3 | ≤0.5 | ≤4.0 | ≤5.0 | ≤15.0 |

*NB Conditions of sample(s) . All samples were in good condition*
*This test report shall not be reproduced except infull, without written approval of the laboratory.*
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*The Results relate only to items tested*

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Authorised by: Technical signatory; Name S.MAVUNGA Signature ........ Date 17/12/2018

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Environmental Protection Department
Analytical Services
2018 -12- 17
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KGVI, HARARE
Tel: 792772 Email: emalab@ema.co.zw
Website: www.ema.co.zw

**Heavy Metals**

| Customer Ref | | | | | Sample 9 | Sample 10 | Sample 11 | Sample 12 | EMA( Effluent & Solid Waste Disposal) Regulations 2007 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Type of Sample | | | | | River | River | River | River | | | | | |
| Sampling type/plan | | | | | Grab/Random | Grab/Random | Grab/Random | Grab/Random | | | | | |
| Lab ref number | | | | | 186071 | 186072 | 186073 | 186074 | Blue | | Green | Yellow | Red |
| | | | | | | | | | Sensitive | Normal | | | |
| Date sample taken | | | | | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 | | | | | |
| Date sample received | | | | | 16/11/2018 | 16/11/2018 | 16/11/2018 | 16/11/2018 | | | | | |
| Parameters | Units | Method | Status | Uncertainity of Measurement (±) | | | | | | | | | |
| Arsenic | mg/l As | AAS Hydride Generator S | SA | 0.0217 | <0.01 | <0.01 | <0.01 | <0.01 | ≤0.05 | ≤0.05 | ≤0.1 | ≤0.15 | ≤0.3 |
| Cadmium | mg/l Cd | AAS Flame SOP/CM22 | SA | 0.0261 | <0.01 | <0.01 | <0.01 | <0.01 | ≤0.01 | ≤0.01 | ≤0.05 | ≤0.1 | ≤0.3 |
| Copper | mg/l Cu | AAS Flame SOP/CM22 | SA | 0.0436 | <0.01 | <0.01 | <0.01 | <0.01 | ≤1.0 | ≤1.0 | ≤2.0 | <3.0 | <5.0 |
| Iron | mg/l Fe | AAS Flame SOP/CM22 | SA | 0.1252 | 0.80 | **3.14** | **1.89** | **9.90** | ≤0.3 | ≤1.0 | ≤2.0 | ≤5.0 | ≤8.0 |
| Manganese | mg/l Mn | AAS Flame SOP/CM22 | SA | 0.0051 | 0.03 | **0.50** | 0.05 | 0.05 | ≤0.1 | ≤0.1 | ≤0.3 | ≤0.4 | ≤0.5 |
| Nickel | mg/l Ni | AAS Flame SOP/CM22 | SA | 0.0436 | <0.01 | <0.01 | 0.09 | 0.09 | ≤0.3 | ≤0.3 | ≤0.6 | ≤0.9 | ≤1.5 |
| Lead | mg/l Pb | AAS Flame SOP/CM22 | SA | 0.0261 | 0.03 | 0.06 | **0.08** | **0.14** | ≤0.05 | ≤0.05 | ≤0.1 | ≤0.2 | ≤0.5 |
| Mercury (Hg) | mg/l | AAS Hydride Generator S | SA | 0.0002 | <0.01 | <0.01 | <0.01 | <0.01 | ≤0.01 | ≤0.01 | ≤0.02 | ≤0.03 | ≤0.05 |
| Zinc | mg/l Zn | AAS Flame SOP/CM22 | SA | 0.0003 | <0.01 | 0.02 | <0.01 | 0.04 | ≤0.3 | ≤0.5 | ≤4.0 | ≤5.0 | ≤15.0 |

*__NB__ Conditions of sample(s). All samples were in good condition*
*This test report shall not be reproduced except infull, without written approval of the laboratory.*
*For results sent by email or fax, the EMAL shall not be responsible for any changes that may be made to this test report. All EMAL official test reports have an original signature and official stamp*
*Results marked in the status column "SA" (SADCAS Accredited)"in this report are included in the SADCAS Schedule of Accreditation for this Laboratory*
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*The Results relate only to items tested*

**Compiled by:** Name C.A.Chikengu Signature [signature] Date 17/12/18

**Authorised by: Technical signatory: Name** S. MANUNGA **Signature** [signature] **Date** 17/12/2018

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# Appendix 6 - Chi-square Test: Urban Gadgets and E-Waste

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Most urban households in Harare have more than five electronic gadgets * Electronic waste are dominant in urban areas Cross Tabulation | | | | | | | | |
| | | | Electronic waste is dominant in urban areas | | | | | Total |
| | | | Disagree | Strongly Disagree | Neutral | Agree | Strongly Agree | |
| Most urban households in Harare have more than five electronic gadgets | Disagree | Count | 1 | 0 | 1 | 1 | 0 | 3 |
| | | Expected Count | .1 | 0 | .2 | .8 | 2.0 | 3.0 |
| | Neutral | Count | 0 | 0 | 2 | 1 | 2 | 5 |
| | | Expected Count | .1 | 0 | .3 | 1.3 | 3.3 | 5.0 |
| | Agree | Count | 0 | 0 | 2 | 16 | 7 | 25 |
| | | Expected Count | .4 | 0 | 1.6 | 6.5 | 16.5 | 25.0 |
| | Strongly Agree | Count | 1 | 0 | 2 | 11 | 65 | 79 |
| | | Expected Count | 1.4 | 0 | 4.9 | 20.5 | 52.2 | 79.0 |
| Total | | Count | 2 | 0 | 7 | 29 | 74 | 112 |
| | | Expected Count | 2.0 | 0 | 7.0 | 29.0 | 74.0 | 112.0 |

| **Chi-Square Tests** | | | |
|---|---|---|---|
| | Value | Df | Asymp. Sig. (2-sided) |
| Pearson Chi-Square | 61.523[a] | 9 | .000 |
| Likelihood Ratio | 43.101 | 9 | .000 |
| Linear-by-Linear Association | 31.307 | 1 | .000 |
| N of Valid Cases | 112 | | |
| a. 12 cells (75.0%) have expected count less than 5. The minimum expected count is .05. | | | |

Appendix 7 - Clearance letter from Harare City Council

CITY OF HARARE

HUMAN CAPITAL DEPARTMENT
TOWN HOUSE, HARARE, ZIMBABWE
POST OFFICE BOX 990
TELEPHONE 752979 / 753000

EMAIL: hrd@hararecity.co.zw
ADDRESS ALL CORRESPONDENCE TO THE HUMAN CAPITAL DIRECTOR

University of South Africa

16 November 2018

Dear Benjamin Mandevere

**RE: AUTHORITY TO UNDERTAKE RESEARCH: BENJAMIN MANDEVERE.**

This letter serves as authority for Benjamin Mandevere to undertake a research project on the topic: **"ASSESSMENT OF ELECTRONIC WASTE MANAGEMENT IN HARARE, ZIMBABWE".**

The City of Harare has no financial obligation and neither shall it render any further assistance in the conduct of the research. The researcher is however requested to avail a soft and hard copy of the research to the undersigned so that residents of Harare can benefit out of it. The research should not be used for any other purpose other than the study purpose specified.

Yours faithfully

**RTD MAJOR M. MARARA**
**ACTING HUMAN CAPITAL DIRECTOR**

CITY OF HARARE
HUMAN RESOURCES DEPT.
16 NOV 2018
P.O. BOX 990, HARARE
TEL. 752979

**Harare to achieve a WORLD CLASS CITY STATUS by 2025**

## Appendix 8- PARTICIPANT INFORMATION SHEET

Ethics clearance reference number: 2017/CAES/159

Research permission reference number: REC-170616-051

**TITLE:** Assessment of Electronic Waste Management in Harare, Zimbabwe

**Dear Prospective Participant**

My name is Mr Benjamin Mandevere and I am doing research with Dr Herman Wiechers, a supervisor in the Department of Environmental Studies, towards a PhD at the University of South Africa. We are inviting you to participate in a study entitled: ***Assessment of Electronic Waste Management in Harare, Zimbabwe***

**WHAT IS THE PURPOSE OF THE STUDY?**

I am conducting this research to find out the state, nature and distribution of electronic waste in Harare, Zimbabwe. The study will look at the management of electronic waste in Harare, as well as assessing the current Zimbabwean environmental legislations, to see the extent it goes to in dealing with electronic waste. The research will also include the testing of soils and water samples to establish the levels of electronic waste pollution in Harare, Zimbabwe. An assessment will also be made to see the levels of understanding of the effects of e-waste to human health and the environment by the population of Harare.

**WHY AM I BEING INVITED TO PARTICIPATE?**

You are being invited to participate because you are a resident(s) of Harare and the research is looking at an issue that is affecting Harare. It is important to note that your institution has identified you as an expert in the discipline under discussion and this is the reason why you are being selected. Please note that there are about 300 participants in this research across Harare who will be helping me (the researcher) with information from different ministries, government departments, non-governmental organizations as well as households.

**WHAT IS THE NATURE OF MY PARTICIPATION IN THIS STUDY?**

Your role in the study will be to help the researcher by answering various questions during the interview (involves audio recording), complete questionnaires and participating in group discussions. Questions that will be asked involves how e-waste should be managed, health and environmental problems resulting from e-waste, effectiveness of the different legislation handling e-waste in Zimbabwe, level of understanding of e-waste among the residents of Harare and other issues surrounding e-waste management in Harare, Zimbabwe. You are expected to take about 10 minutes to complete a questionnaire, and interviews will take about 15 minutes, while group discussion will not go beyond an hour. Ultimately, your role is to provide as much information as possible on electronic waste management in Harare, Zimbabwe.

**CAN I WITHDRAW FROM THIS STUDY EVEN AFTER HAVING AGREED TO PARTICIPATE?**

Participating in this study is voluntary and you are under no obligation to consent to participation. If you do decide to take part, you will be given this information sheet to keep and be asked to sign a written consent form. You are however free to withdraw from participating at any stage of the research.

**WHAT ARE THE POTENTIAL BENEFITS OF TAKING PART IN THIS STUDY?**

It is important to note that there will be no individual or group financial gains to participating in this research. It is however important to note that the results of this research to which you would have contributed, will help Harare and Zimbabwe at large know the state of her electronic waste management and thus enabling her to prepare for the future of the current as well as that of the future generation. This will thus benefit you as a Zimbabwean and others to include your siblings and generations to come.

**ARE THERE ANY NEGATIVE CONSEQUENCES FOR ME IF I PARTICIPATE IN THE RESEARCH PROJECT?**

Please note that the times indicated may be slightly longer during the data gathering process. It must however be noted that the researcher will try his very best to stay within the time limits specified and should this fail, it is expected not to take more than 5-10 minutes longer than estimated.

**WILL THE INFORMATION THAT I CONVEY TO THE RESEARCHER AND MY IDENTITY BE KEPT CONFIDENTIAL?**

Please note that your name, contact number, physical address or office number will not be formally recorded anywhere, and apart from the researcher and identified members of the research team, no one else will know about your involvement in this research. Your answers will be given a code number, or a pseudonym and you will be referred to in this way in the data, as well as in any publications. The data will not be given to any newspapers, individuals or institutions, except those that are directly involved in the research and who are under obligation to keep this information strictly confidential and for academic reasons alone.

The data will be seen by the researcher, his assistant(s) and in some cases, transcriber, external coders and members of the research ethics review committee only, and no one else. After the processing of the data, the University will mark the document and once satisfied, ministries involved, and other government departments will get soft (pdf) and hard copies.

Please be informed that the data you provide may also be used for other purposes such as a research report, journal article(s) and/or conference proceedings. In light of this, be assured that even if the data is used for such, no individual or organizational names will be revealed in the articles, thus the information remains anonymous and only attached to the researcher's name.

In cases where group discussions are held, please note that, while every effort will be made by the researcher to ensure that you will not be connected to the information that you share during the focus group, the researcher cannot guarantee that other participants in the focus group will treat information confidentially. Nonetheless, all participants will be encouraged to do so. For this reason, you are advised not to disclose personally sensitive information in the focus group.

**HOW WILL THE RESEARCHER(S) PROTECT THE SECURITY OF DATA?**

Hard copies of your answers will be stored by the researcher for a period of five years in a locked cupboard/filing cabinet at his place of residence at Plot 341 Rainham, Zvimba. This is for future research or academic purposes; electronic information will be stored on a password protected computer and external hard drive. Future use of the stored data will be subject to further Research Ethics Review and approval, if applicable. After five years, hard copies will be shredded, and/or electronic copies will be permanently deleted from the hard drive of the computer using a relevant software program.

**WILL I RECEIVE PAYMENT OR ANY INCENTIVES FOR PARTICIPATING IN THIS STUDY?**

Please be advised that there will be no incentives attached to your participation. Your contribution will be strictly to assist the researcher with vital information for academic use. Your contributions will be highly valued although no monitory value will be attached to it.

**HAS THE STUDY RECEIVED ETHICS APPROVAL?**

This study has received written approval from the Research Ethics Review Committee of the College of Agriculture and Environmental Sciences, UNISA. A copy of the approval letter can be obtained from the researcher if you so wish.

**HOW WILL I BE INFORMED OF THE FINDINGS/RESULTS OF THE RESEARCH?**

If you would like to be informed of the final research findings, please contact ***Mr Mandevere Benjamin*** on +26 377 3235572 or +26 371 2351081 or email him at nhongobenji@gmail.com. The findings are accessible for 5 years from the date of completion of the study. You can use departmental and or mobile phone numbers to contact the researcher.

Should you require any further information or want to contact the researcher about any aspect of this study, please contact ***Mr Mandevere Benjamin*** at +26 371 3500082 or email him at 51356244@mylife.unisa.ac.za.

Should you have concerns about the way in which the research has been conducted, you may contact Dr Herman Wiechers at +27 82 953.7977 or email him at herman@wiechers.online. Contact the research ethics chairperson of the CAES General Ethics Review Committee, Prof EL Kempen on 011 471.2241 or kempeel@unisa.ac.za if you have any ethical concerns.

Thank you for taking time to read this information sheet and for participating in this study.

Thank you.

Insert signature

…………………………………………………………………………………………………….

Type your name

…………………………………………………………………………………………………….

## Appendix 9 - CONSENT TO PARTICIPATE IN THIS STUDY

I, ………………………………………………. confirm that the person asking my consent to take part in this research has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty.

I am aware that the findings of this study will be processed into a research report, journal publications and/or conference proceedings, but that my participation will be kept confidential unless otherwise specified.

I agree to the recording of the interview audio.

I have received a signed copy of the informed consent agreement.

Participant Name & Surname ……………………………………………………………………….

Participant Signature…………………………………………Date…………………………………….

Researcher's Name & Surname…………………MANDEVERE BENJAMIN………………………

Researcher's signature………………………………………… Date…………………………………

Appendix 10 - Ethics Approval

UNISA university of south africa

**CAES HEALTH RESEARCH ETHICS COMMITTEE**

Date: 08/01/2019

Dear Mr Mandevere

NHREC Registration # : REC-170616-051
REC Reference # : 2017/CAES/159
Name : Mr B Mandevere
Student #: 51356244

**Decision: Ethics Approval Renewal after First review from 01/02/2019 to 31/01/2020**

**Researcher(s):** Mr B Mandevere
51356244@mylife.unisa.ac.za

**Supervisor (s):** Dr H Wiechers
herman@wiechers.online; 082-953-7977

**Working title of research:**

Assessment of electronic waste management in Zimbabwe

**Qualification:** PhD Environmental Science

Thank you for the submission of your progress report to the CAES Health Research Ethics Committee for the above mentioned research. Ethics approval is renewed for a one-year period. After one year the researcher is required to submit a progress report, upon which the ethics clearance may be renewed for another year.

**Due date for progress report: 31 January 2020**

*The* ***low risk application*** *was* ***reviewed*** *by the CAES Health Research Ethics Committee on 01 February 2018 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.*

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.

University of South Africa

2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the Committee.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.
5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.
6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data require additional ethics clearance.
7. No field work activities may continue after the expiry date. Submission of a completed research ethics progress report will constitute an application for renewal of Ethics Research Committee approval.

*Note:*
*The reference number **2017/CAES/159** should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.*

Yours sincerely,

**Prof EL Kempen**
**Chair of CAES Health REC**
E-mail: kempeel@unisa.ac.za
Tel: (011) 471-2241

**Prof MJ Linington**
**Executive Dean : CAES**
E-mail: lininmj@unisa.ac.za
Tel: (011) 471-3806



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