International Journal of Science and Research Archive

eISSN: 2582-8185

Cross Ref DOI: 10.30574/ijsra

Journal homepage: https://ijsra.net/

(RESEARCH ARTICLE)

Environmental and health hazards associated with poor electronic-waste management: Knowledge gaps among electronic consumers in Zambia

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International Journal of Science and Research Archive, 2025, 14(03), 1706-1725

Publication history: Received on 03 January 2025; revised on 28 March 2025; accepted on 30 March 2025

Article DOI: https://doi.org/10.30574/ijsra.2025.14.3.0446

Abstract

Purpose: This paper explores electronic (e) waste, its associated environmental and health hazards, and the perspectives of electrical and electronic equipment (EEE) consumers in Zambia. It uses the theory of planned behaviour and Capability approach to establish the interlinkedness between EEE consumers' knowledge of e-waste hazards and their e-waste management practices. This stems from a growing concern on poor e-waste management for developing economies in Sub-Saharan Africa. E-waste is ranked the most rapidly expanding solid waste stream globally, growing three times faster than the world's population. The 2024 Global E-waste Monitor report estimates that around 20 to 50 million metric tons of e-waste are produced worldwide, annually. E-waste has been on the rise due to modern society's increased use and dependence on electrical and electronic equipment. This happens when an electrical and electronic device reaches its end of life cycle, quickly becoming obsolete. If improperly managed, recycled or disposed, e-waste presents irreversible environmental and health consequences. In Zambia, the desire for cutting-edge technology, mostly imported from the West, but met with inadequate e-waste handling facilities is skyrocketing. This paper argues that a persistence in e-waste knowledge gaps and inadequate e-waste management mechanisms, result in poor e-waste management, thereby compromising environmental and human wellbeing.

Methods: This mixed methods study included 299 participants: 226 EEE consumers and 3 environmental entities and waste aggregators. This article analyzes and presents empirical findings from EEE consumers on e-waste sources/origins, associated hazards, consumers' understanding, and e-waste management practices. Data was collected using questionnaires and interviews. To analyse the data, Statistical Package for the Social Sciences (SPSS) was used.

Results and conclusion: Findings show that e-waste in Zambia largely exists in form of information and communication technologies, large and small electronic equipment. Common hazardous substances include lead (Pb), Arsenic (As), Cadmium (Cd) and Mercury (Mg). These are deposited into the environment, facilitated by poor waste segregation traits, inability of EEE consumers to trace e-waste sources, and inadequacies in e-waste management education and facilities. Findings show that knowledge of hazards linked to e-waste is generally low among EEE consumers in Zambia. Data further reveals a correlation between the comprehension of e-waste and perspectives on the acquisition, utilization and disposal of EEEs. E-waste disposed of at landfills and present in-home environments contributes to environmental degradation, including pollution and climate change, as well as posing risks to human health, such as respiratory illnesses. The paper concludes that in the absence of environmentally informed EEE consumers and effective e-waste management mechanisms, the e-waste burden will only worsen for developing economies like Zambia. There is urgent need for the enhancement of e-waste education; strengthening of e-waste regulatory frameworks; establishment of inventories; strengthening avenues for e-waste buyback schemes and re-evaluation of existing e-waste management facilities in Zambia.

Keywords: Electronic Waste; Knowledge; Practices; Theory of Planned Behavior; Capability Approach

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1. Introduction

The 2024 Global E-waste Monitor report [1] estimates that around 20 to 50 million metric tons of electronic waste (hereinafter e-waste) are produced worldwide annually. From 2010 to 2022, e-waste generation has surged by as much as 82%. Various global studies [2, 3] provide a holistic account of global e-waste trends. More than 70% of e-waste is deposited to developing nations [1,3] Some of this e-waste originates for illegal transboundary imports from the USA, Europe and China [3]). According to Forti et.al (2020 p.9), in 2019, about 53.6 million metric tons (Mt) of e-waste was generated on a global scale, increasing by 1.8Mt as of 2014 [4]. However, less than 20% of this generated e-waste was officially accounted for, while the collection and recycling trends remain poorly documented.

Moreover, fewer than 30% is recycled by lawful means, particularly in Asia and Africa [5,6,7]. E-waste, or waste of electrical and electronic equipment (WEEE), is the most rapidly expanding solid waste stream globally, growing three times faster than the world's population. Such statistics are indicative that the increase in global e-waste hardly tallies with the recycling mechanism therein. Moreover, sustainably managing e-waste is now more than ever a crucial, especially for developing countries like Zambia. Significantly, the generation of e-waste is influenced by population demographics, temporal factors, geographical location, socioeconomic status, and prevailing lifestyles [8,4]. Showkat (2022 p.17) notes that most individuals are likely 'oblivious' to it [9].

1.1. E-waste knowledge and e-waste management practices: A nexus.

Research indicates that the awareness of EEE consumers regarding e-waste management is crucial for comprehending its administration. Insufficient understanding regarding hazardous e-waste and appropriate disposal methods impedes effective e-waste recycling [10]. Chibunna et al. (2012) note that inadequate understanding of e-waste management stems from a deficiency of knowledge regarding proper e-waste disposal methods. The findings align with Uhunamure et al. (2021), whose research in Limpopo, South Africa, demonstrated that knowledge and perception of e-waste are the principal determinants in fostering appropriate waste management intentions. The research indicated that 76% of participants perceived e-waste streams as having a detrimental impact on their environment. The study advocated for awareness and educational initiatives to alter families' perceptions of e-waste and environmental conscience [11, 12]. Maphosa & Maphosa (2020) observe that insufficient public awareness regarding e-waste management and recycling presents a barrier in managing this intricate waste stream [13]. Consequently, educating consumers on the health risks and disposal methods of e-waste is crucial for mitigating environmental dangers and protecting human health [14]. These studies markedly illustrate the relationship between knowledge and practices about e-waste management. From a Zambian perspective, however, it remains empirically unclear the primary sources of e-waste, EEE consumers' knowledge, and how these interplay in view of e-waste associated hazards.

1.2. Problematizing e-waste in Zambia

Zambia is familiar with the utilization of EEEs, as consumer adoption has increased significantly over the years. In 2023, the imports of EEEs in Zambia amounted to around USD 360 million [15]. The rise in EEEs available in the market indicates a likely escalation in e-waste production in Zambia. Due to environmental and human concerns related to e-waste, its appropriate management is essential [16, 17]. E-waste, owing to its composition of several hazardous substances, presents significant environmental and human hazards if inadequately treated [18]. Although the availability and extensive utilization of EEEs have become essential to human existence, Forti et al. (2020) express concern on the unsustainability of their manufacture, usage, and disposal [4]. These substances contribute to pollution of water, land, and air [10]. Inadequate management, recycling, and disposal of electronic trash can significantly affect public health and the environment [19]. Toxins from e-waste have been linked to brain damage, congenital anomalies, allergic responses, and cancer [20] Table 1 below delineates the hazardous constituents of e-waste as illustrated in the 2023 Zambia e-waste plan [21].

Table 1 Substance composition of e-waste

Substance	**Occurrence in E-waste**
Heavy and other metals	
Arsenic	Small quantities in the form of gallium arsenide within light emitting diodes
Barium	Getters in CRT
Beryllium	Power supply boxes containing silicon-controlled rectifiers and x-ray lenses
Cadmium	Rechargeable NiCd-batteries, fluorescent layer (CRT screens), printer inks and toners, photocopying-machines
Chromium VI	Data tapes, floppy-disks
Lead	CRT screens, batteries, printed wiring boards
Lithium	Li-batteries
Mercury	Fluorescent lamps that provide backlighting I LCDS, in some alkaline batteries and mercury wetted switches
Nickel	Rechargeable NiCd-batteries or NiMH-batteries, electron gun in CRT
Rare Earth elements (Yttrium, Europium)	Fluorescent layer (CRT-screen)
Selenium	Outdated photocopying machines
Zinc Sulphide	Inferior of CRT screens, mixed with rare earth metals
Halogenated compounds	
Polychlorinated biphenyls (PCBs)	Transformers, Condensers
Polybrominated biphenyls (PBBs) Polybrominated diphenyl ethers (PBDE) Tetrabromo-biphenol-A (TBBA)	Fires retardants for plastics (thermoplastic components, cable installation) TBBA is currently the predominantly used flame retardant in print
Chlorofluorocarbons (CFC)	Cooling units, insulation foam

Source: Zambia statistics agency (2023).

The management of e-waste in Zambia is an increasing concern, and scholars have examined the issue from several perspectives. For example, Sanana and Mwanza (2024) aimed to evaluate the issues of E-waste management in Zambia. The research indicated that substantial difficulties define the management of e-waste in Zambia. These encompass a deficiency in recycling technology, infrastructural inefficiencies, and insufficient funding and investment. The growth of EEEs in Zambia, similar to other developing nations, arises from diverse origins and mechanisms. However, many of these electrical and electronic equipment (EEEs) are second-hand, of low quality, and often nearing their end of product life cycle. Research indicates that minimum standards for ICTs received in Zambia and adjacent countries are absent. Consequently, while such EEEs may be functional for a limited duration, they rapidly become obsolete [16, 22].

The societal groups most vulnerable to the hazards associated with e-waste are the elderly, pregnant women, foetuses, toddlers, and individuals with physical disabilities. Some individuals are landfill scavengers and others engaged in the informal recycling of e-waste [23]. The e-waste issue is more pronounced in underdeveloped countries compared to developed nations, while being a global concern. This is due to the existence of effective e-waste management systems in developed nations, which are governed by specific legislation concerning e-waste [24]. Consequently, the environmental and human repercussions of e-waste place less developed economies, such as Zambia, at heightened risk. While e-waste is predominantly produced in rich countries, a significant portion is shipped to developing regions, such as Africa and specifically Zambia. This indicates that developing nations must implement substantial measures for effective management [25]. Despite several studies addressing the e-waste issue in the African and Zambian contexts

[16,17, 26], a lacuna persists in understanding the e-waste management situation in Zambia, specifically in view of the nexus between EEE consumer knowledge and e-waste management practices. Hence this paper.

1.3. Aim and objectives

This paper examines the e-waste knowledge and management practices of consumers of electrical and electronic equipment (EEEs). The subsequent questions are explored.

- What are the primary sources of e-waste in Zambia?
- What are the perceptions regarding e-waste and its associated dangers among consumers of electrical and electronic equipment?
- What are the e-waste management practices among consumers of electrical and electronic equipment?

The first research objective aims to identify the frequently utilized EEEs within the chosen population. The second seeks to comprehend the varying perceptions of e-waste and its potential human and environmental consequences. The third purpose is prompted by the necessity to evaluate e-waste management practices in Zambia.

2. Literature review

2.1. E-waste sources, pathways and associated environmental/human threats

Numerous scholars have similarly categorized EEEs and sources of e-waste [10, 27, 28, 29]. When these electronic and electrical equipment become dysfunctional, obsolete, and discarded, e-waste is generated [30]. This document defines e-waste as outdated and non-functional electrical and electronic equipment (EEEs). These have either achieved or are approaching the conclusion of their product life cycle. The Step Initiative (2014) defines EEEs as devices with electrical or circuitry components that include a battery or power supply [31]. This study summarizes examples of e-waste sources as delineated by the European Union [32].

E-waste generally consists of hazardous and non-hazardous metals and non-metals. Typical e-waste comprises, but is not limited to, the following examples: Organics, such as glass fibre and polymers; inorganics, including non-ferrous metals; ceramics, comprising silica and alumina. Base metals: Copper (Cu) and Iron (Fe); Heavy metals, such as Mercury (Hg) and Lead (Pb); Noble metals, including Silver (Ag) and Gold (Au); Rare earth metals, for instance, Tantalum (Ta) and Gallium (Ga). E-waste has about 1,000 distinct chemicals, including arsenic, cadmium, selenium, hexavalent chromium, and flame retardants, which emit dioxins when incinerated [33,34,29]. These are categorised in table 2 below.

Table 2 Categorization of EEEs amounting to potential e-waste

EEE category	Example
Small household appliances	Coffee machines, wall clock, pressing iron, toaster, vacuum cleaner
Large household appliances	Refrigerator, electric stoves washing machine, air conditioner
IT and Telecommunication equipment	Personal computers laptop, mobile phone
Consumer equipment	Television, radio, VCD, DVD
Lighting equipment	Compact fluorescent lamps, Luminaries for fluorescent lamps
Electrical and electronic tools	Sewing machine, Drills, equipment for turning, milling, sanding e.g for processing wood, or metal
Toys, Leisure and sports equipment	Video games, electric baby dolls, Electric trains and car racing sets
Medical devices	Radiotherapy equipment, Cardiology, Dialysis and Pulmonary ventilator
Monitoring and control instruments	Smoke detector. Heat regulator, thermostats
Automatic dispensers	Automatic dispensers for hot or cold drinks, bottles or cans

Adapted from Alabiet.al 2021 drawing from Antrekowitsch et.al 2006 in accordance with EU directives of e-waste [35].

Literature on the environmental and human-related hazards of e-waste has been extensively examined [8, 32, 36, 37] the impact of e-waste on the environment and human health as interconnected issues. Human health is significantly reliant on environmental quality; hence, any compromise to the environment adversely impacts individuals. For instance, when e-waste materials are emitted into the atmosphere, humans inhale, absorb, and consume the pollutants primarily via dust. The build-up of heavy metals attains dangerous concentrations under different environmental situations, endangering both the ecosystem and human health [38]. The rise in e-waste issues primarily arises from inadequate management practices, and in certain instances, the illegal recycling and disassembly of electrical and electronic equipment (EEEs). These 'backyard' operations [32] have intensified environmental contamination. Contamination from e-waste is influenced by several elements, including acid rain, heavy metal content, and synthetic compounds. E-waste frequently enters the environment, either through landfills or inadequate recycling efforts. Consequently, e-waste generates chemicals derived from the various compositions of electrical and electronic equipment already mentioned. These potentially deleterious compounds permeate the soil, so polluting it. The pathways of e-waste within the environment are illustrated in figure 1 below.

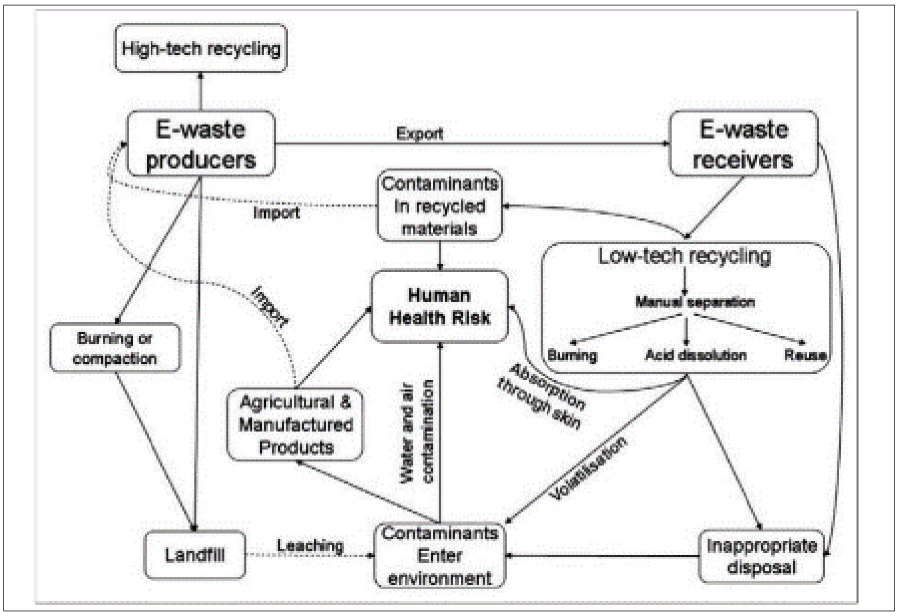

Figure 1 E-waste pathways. Adapted from Robinson 2009; Meem et.al 2021[3]

The penetration of e-waste toxins within the environment is dynamic. For example, the movements and advancement of soil contamination are influenced by various ecological parameters, including pH, adsorption-desorption processes, the composition of organic matter, temperature, and other intricate chemical characteristics of specific e-waste materials [3, 36]. Soil contaminated with e-waste contaminants deteriorates in quality, adversely impacting its health, fertility, and safety for human utilization. Furthermore, e-waste contamination leads to air pollution. According to Agency for Toxic Substances and Disease Registry (2012), humans can potentially be exposed to e-waste pollutants via soil, water, and food products like as meat [39]. In addition to these instances, e-waste pollutants are disseminated into the environment via several channels, including the atmosphere, water, soil, and human populations. These, thus, jeopardize environmental quality and present risks to human health.

2.2. The dark side of the modern age and the urgency for effective e-waste management

Many African nations, akin to the global community, endeavour to achieve sustainable development in alignment with the Sustainable Development Goals (SDGs) and Agenda 2063. Scholars note that a digitally interconnected world is fundamental [40, 41, 42]. Nevertheless, the production of e-waste is significantly escalating. A study by Maphosa & Maphosa (2020) revealed that despite the rapid generation of e-waste, numerous countries lack the necessary legislation and infrastructure for its effective management [13]. In sub-Saharan Africa, there are no regulations particularly regulating e-waste. In many instances, there is a significant dependence on hazardous waste legislation integrated with existing legal systems. The management of e-waste is a fast-expanding domain for addressing global environmental issues [43]. The effective management of e-waste encompasses reuse, regulated recycling, material recovery, incineration, and landfilling [29]. At present, the majority of e-waste generated in low and middle-income nations is unregulated and handled by the informal sector using rudimentary methods, including informal dismantling, unskilled recycling, open dumping, unmonitored landfill disposal, and open burning, thereby exposing the public to the hazardous effects of e-waste [19, 40]. This study contends that the inadequate management of e-waste is mostly driven by deficiencies in understanding and current e-waste management systems.

3. Theoretical underpinning

This paper utilizes Ajzen's (1991) Theory of Planned Behaviour (TPB) and Sen's (1985; 1999) Capability Approach (CA) [44, 45, 46] to examine the knowledge and practices on e-waste among EEE consumers in Zambia. The Theory of Planned Behaviour (TPB) has been extensively applied in environmental studies, including waste recycling [47] sustainable water and energy consumption [48] and low carbon consumption [49]. Utilizing the TPB is advantageous for identifying the determinants of environmental behaviour [50] can then facilitate successful solutions for particular environmental issues. The TPB posits that conduct is determined by intention and perceived behavioural control. I utilize four elements of the TPB to examine the knowledge and practices among EEE consumers regarding e-waste as summarised in table 3 below.

Table 3 Constructs of the theory of planned behavior for determining e-waste practices

Subjective norms	An individual's convictions regarding the significance that social groupings attribute to the expectation of engaging in a particular behaviour.
Perceived power	Perceived existence of elements that may enhance or hinder the execution of a behaviour.
Attitudes	It involves an evaluation of the consequences of doing the behaviour.
Behavioural intention -	This pertains to the motivational elements that affect a specific activity, indicating that a stronger intention to engage in the conduct correlates with a higher likelihood of its execution.

The TPB forecasts an individual's intention to do a behavior at a designated time and location [51]. The aim was to elucidate all behaviors subject to self-control by individuals. Understanding e-waste management habits among EEE consumers requires an examination of the factors influencing the acquisition, utilization, and management of electronics. Nonetheless, apprehensions persist regarding the comprehensiveness and efficacy of the TPB in forecasting ecologically oriented (green) actions. The TPB is perceived as emphasizing attitudes while disregarding knowledge factors that significantly impact individuals' pro-environmental behaviors. Additionally, other researchers contend that environmental activities are influenced by other elements, including an individual's environmental identity, sense of obligation, and commitment to the environment [51, 52]. In recognition of these constraints, this work enhances the TPB by incorporating the concepts of agency and conversion variables from the Capacity approach (CA). This is predicated on the assertion that pro-environmental attitudes and behaviors are influenced by numerous factors that the TPB appears to overlook. This study asserts that e-waste management, similar to other environmentally sustainable practices, can be affected by individual agency and conversion factors. Furthermore, the adaptability of the TPB [50, 54, 55] and the open-ended, multifunctional characteristics of the CA [56, 57, 58, 59, 60] facilitate the integration of supplementary theories and concepts. This is illustrated in figure 2.

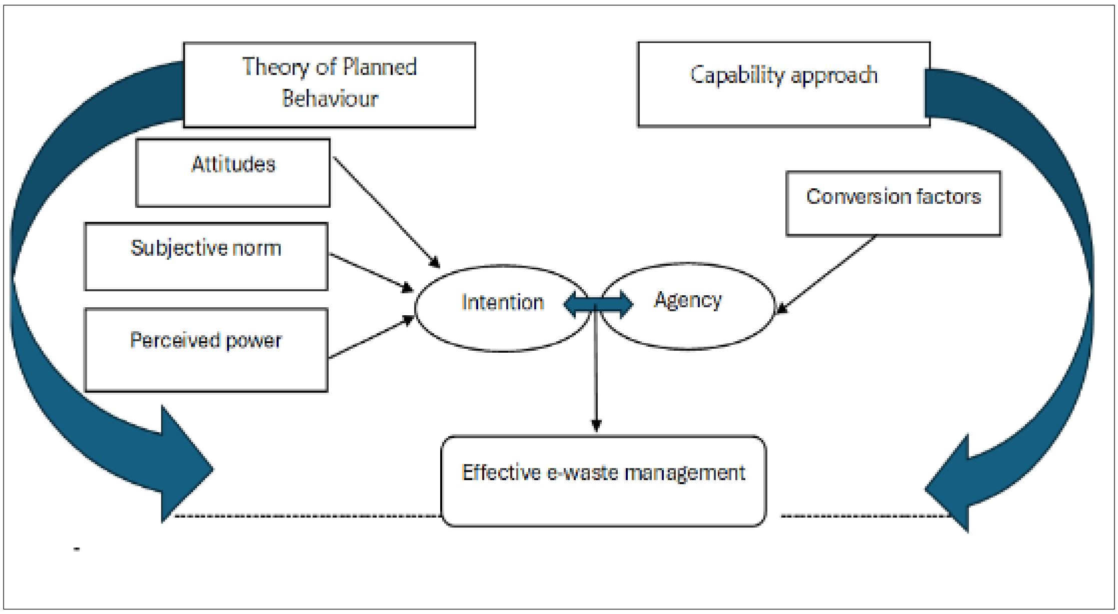

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Figure 2 A TPB-CA framework for investigating knowledge and practices on e-waste.

The capacity approach, established by Amartya Sen in 1999, promotes concepts of human freedoms and well-being. In environmental research, the CA serves as a valuable evaluative framework for comprehending and addressing environmental issues [61, 62,63] particularly in the context of e-waste management in this study. The CA posits that individuals should seek and relish lives they have justifiable reasons to value [45, 64] and exist within a socially equitable society [59, 65]. I specifically utilize two elements of the Capability Approach: agency and conversion factors. Significantly, agency can be regarded as a capability [66]. In other words, it serves as a platform for EEE customers to exhibit their knowledge and proficiently handle their e-waste. According to the CA, a capability represents a potential for functioning, whereas a functioning denotes the condition of 'being' or 'doing' [45]. Agency in the CA denotes the capacity to make decisions and execute such decisions. It signifies an individual's capacity to deliberately engage in an action aligned with their values. This study associate's agency with concepts of responsibility, autonomy, and the decision to engage in ecologically sustainable practices concerning e-waste management. One's agency in sustainably using EEEs and efficiently managing e-waste can be influenced by several personal, environmental, and societal conversion variables. Conversion factors in the CA) denote elements that positively or negatively affect the attainment of valued capabilities [60]. This study argues that consumers of EEEs are influenced by various conversion factors, which subsequently affect their actions in e-waste management. Through the TPB-CA framework, this study provides a nuanced examination into attitudes in relation to intention and their impact on sustainable e-waste management practices. This framework enables us to explore additional complex aspects that influence this phenomenon.

4. Methodological approach

4.1. Study area

The study was conducted in Lusaka, the capital and most populace city of Zambia. It is situated in south-central Zambia at 15°25′S 28°17′E, on a plateau at an elevation of 1300 m (4265 feet). The estimated population is 3,079,964 [67]. This research was carried out among homes in the South-Eastern region of Lusaka.

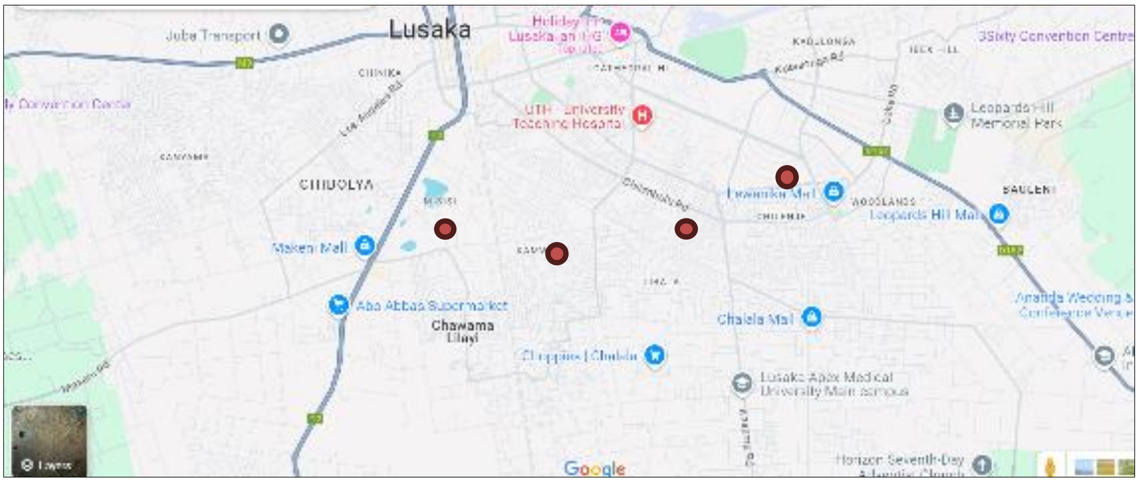

Figure 3 Geographical location of study area

4.2. The research was conducted in designated locations

4.2.1. Sample Size and Sampling Procedure

The research included 229 individuals in total. The study utilized two data sources. i) Surveys/questionnaires administered to 226 participants from households, ii) interviews conducted with three environmental entities, including garbage collectors, aggregators, and recyclers. This paper exclusively presents data from EEE consumers at household level. The study concentrates on individual participants recruited from families in four regions of Lusaka province. Households in Libala, Kamwala, Kabulonga, and Woodlands were selected based on the researcher's convenience. Purposive sampling was employed to choose the participants. This study defines EEE consumers as individuals who have owned, utilized, or sold electronic gadgets, including laptops, computers, telephones, refrigerators, fans, and other electronic appliances. Consequently, participants were chosen based on their affirmation of having possessed, utilized, sold, or disposed of an EEE. A mixed-method approach, incorporating both qualitative and quantitative techniques, was utilized. Qualitative data was gathered to understand the views of e-waste among EEE consumers and environmental institutions. Conversely, data regarding the quantity of EEEs, their classifications, and the generation of e-waste was obtained quantitatively. This was also crucial for assessing the knowledge levels among EEE consumers. Data was collected from all participants via hard copy questionnaires, with the researcher available to provide clarification as needed. Data were analysed utilizing the Statistical Package for the Social Sciences (SPSS). This enabled the creation of descriptive representations, like charts, frequencies, and percentages, among others.

5. Findings and discussion

Empirical data was examined and classified into three primary themes: Major sources of e-waste, knowledge of e-waste, and e-waste management practices. I will commence by providing a summary of biodata of the participants in this study, as seen in table 4.

Table 4 Biodata of the respondents who took part in the study by percentage

Gender		Age-Group		Marital Status		Education level	
Female	40.7%	Below 20:	6.2%	Married	45.98%	Never been to school	5.3%
Male	59.3%	20-30	35.4%	Single	52.68%	Primary school	1.8%
		31-40	44.2%	Widowed	1.34%	Grade 9 and below	0.9
		41-50	10.2%			Grade 10 – 12	7.1%
		51-60	1.8%			College level	34.5
		Declined to answer	2.2%			University level	50,4

The majority of participants in this study were aged between 20 and 40 years, and half of the sample had achieved tertiary education.

5.1. Predominant sources of e-waste

Participants were requested to identify and specify the categories of EEEs they had owned, utilized, sold, or disposed of from 2000 to 2020. The participants had and utilized a variety of electronics, encompassing both large and small devices, as well as information and communication technologies (ICTs). Table 5 shows the predominantly used EEEs, potentially amounting to e-waste among selected households.

Table 5 Categories of EEEs owned and use by participants

EEE category	Percentage
Mixed	60.6%
Large	15.9 %
ICTs	15.9%
Small	7.5%

Data indicated that the propensity to acquire electronic devices is significantly associated with heightened economic growth and income levels among Zambian households. The graph below illustrates specific examples of EEEs possessed by the participants.

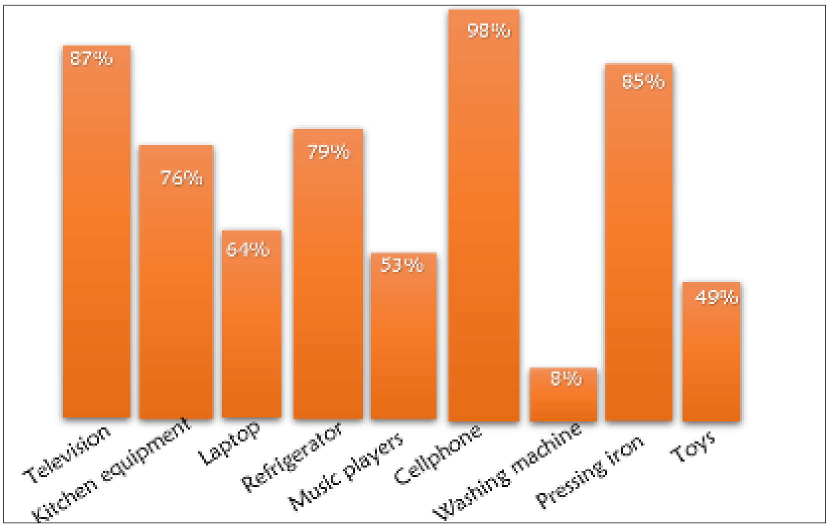

Figure 5 Examples of EEEs owned and used by participants

Data indicated that mobile phones were the most frequently utilized electronic devices at the individual level. To gain insights into the quantity of cell phones utilized by participants across the 20-year period, individuals were inquired about the number of phones they had owned.

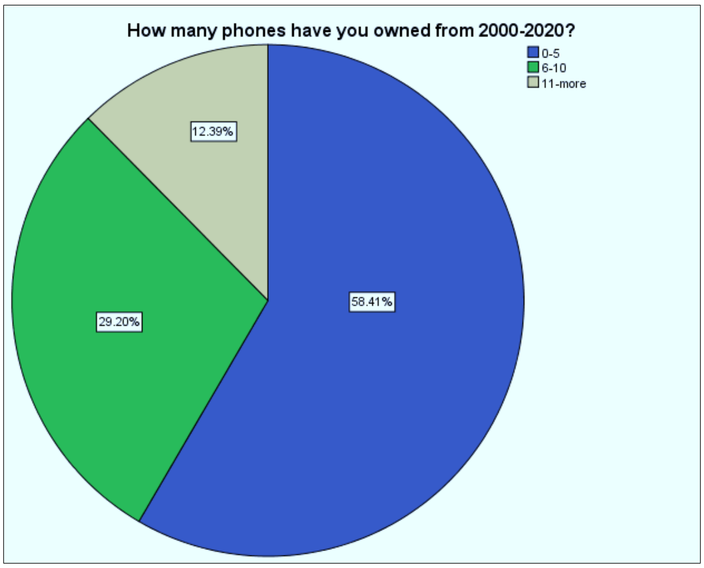

Figure 6 Quantity of mobile phones owned within a 20-year period

The results revealed that 132 respondents possessed between 0 and 5 cell phones over the period from 2000 to 2020. Sixty-six respondents, including 29.20% of the research population, possessed between 6 and 10 mobile phones throughout the specified period, whilst 12.39% of the respondents had owned more than 10 mobile phones. Concerning mobile phone usage, 98.67% of participants acknowledged having replaced their phone batteries with fresh ones. Merely 1.33% of the research population reported that they had never replaced their phone batteries. This data is crucial for comprehending the development of e-waste according to certain categories of electronic equipment.

Nonetheless, these EEEs are upgraded or approach their end-of-life more rapidly, resulting in the generation of e-waste. To gain a clearer understanding of e-waste generation from major household equipment, I inquired whether participants had experienced any instances of such equipment ceasing to work over the designated timeframe. Results are presented in figure 7 below:

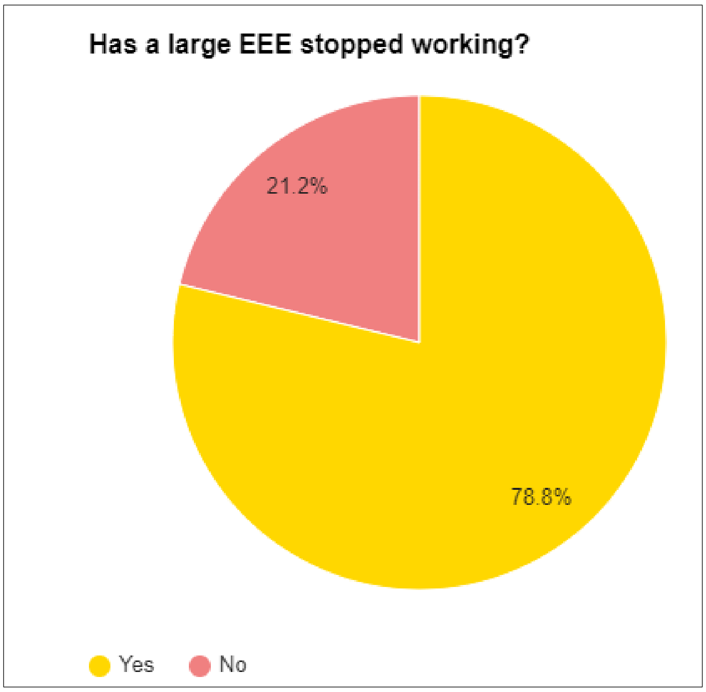

Figure 7 Generation of e-waste from large EEEs

The findings revealed that 178 respondents experienced failures in significant electronic appliances, representing 78.8% of the study population, whereas 48 respondents claimed never facing such problems. This represented only 21.2% of the study population. Significantly, such data indicates the production of e-waste from the sampled population.

5.2. Environmental and health risks associated to e-waste in Zambia

The study's findings indicate that e-waste management techniques render Zambia particularly susceptible to detrimental environmental and human health consequences. The three institutes involved in the study expressed concern on both the escalating quantities of e-waste in the environment and the knowledge deficiencies among EEE consumers. Zambia encounters difficulties regarding the establishment of specific systems for the regulation and management of e-waste. Consequently, e-waste deposited at the Chunga landfill, for instance, is inadequately professionally divided, thus being managed as if it were non-hazardous home waste. This progressively endangers human health, especially as the dumpsite is situated within a densely populated township. Furthermore, environmental contaminants and toxicants can disperse over considerable distances, impacting individuals far off from the disposal site. Furthermore, lead, as a constituent of e-waste, poses a significant threat to human health. The participants indicated that when such components seep into the environment, the health of children is jeopardized. This is primarily owing to children's increased susceptibility to inhaling consequent poisons from play and their proximity to the ground. If mismanaged, lead is a powerful neurotoxin that can cause developmental delays, learning difficulties, behavioural disorders, and health issues. This study demonstrated that e-waste deposited in landfills causes significant environmental deterioration and poses risks to human health. The majority of scavengers in Zambia lack training in the management of hazardous e-waste, thereby increasing their risk of exposure. Nonetheless, e-waste that persists in residential and outdoor settings also contributes to environmental deterioration, pollution, and heightened human health concerns. Table 5 below summarises the findings on environmental and health risks associated to e-waste in Zambia.

Table 5 Environmental and Health associated to e-waste

Vulnerable populations	Toddlers Expectant mothers People with compromised health The public
Vulnerable environments	Local water bodies Ground water Soil Air and open spaces
Identified processes and threats	Leaching into water bodies Leaching into soil within and beyond the landfill E-waste recycling frequently entails incinerating or melting components, hence emitting harmful fumes and particulate particles into the atmosphere. Climate change resulting from increased greenhouse gas emissions during the processing and management of electronic waste materials. Occupational hazards associated with recycling activities conducted by scavengers and inexperienced individuals Destruction of safe habitants for local populations The inhalation of these contaminants may result in respiratory diseases such as asthma, bronchitis, and lung cancer. Other health risks like kidney damage and can increase the (e.g Cadmium, Mercury)
Existing/Possible destinations	Chunga dumpsite Homes Outdoor (broader environment)

The results regarding the impacts of e-waste, its routes, and vulnerabilities align with the literature presented in section 2. Therefore, efficient management of e-waste is essential for the preservation of both the biophysical and human environments in Zambia. E-waste management approaches must consider the trajectories of e-waste and the associated hazards and risks.

5.3. Predominant e-waste management practices

Having comprehended the primary categories of electronic equipment within the research population and associated threats, it was essential to further investigate the management of such waste. Upon inquiry into the management of outmoded household appliances, data indicated that a significant portion of major equipment, such as refrigerators, was either retained within families or distributed to unidentifiable recipients. Participants struggled to recall the locations where such gadgets had been placed. Regarding tiny electronics and ICTs such as mobile phones, data indicated that 38.9% of the sample population disposed of their electronic equipment in waste bins. Forty-nine respondents, constituting 21.7% of the survey population, were unaware of the disposal locations of their previous equipment. Thirty respondents reported having burned their old devices, twenty-seven sold them, twenty-three stored them in drawers, while nine indicated that their old devices had been stolen or had just vanished. The common trends in disposal and management of e-waste are presented in figure 8.

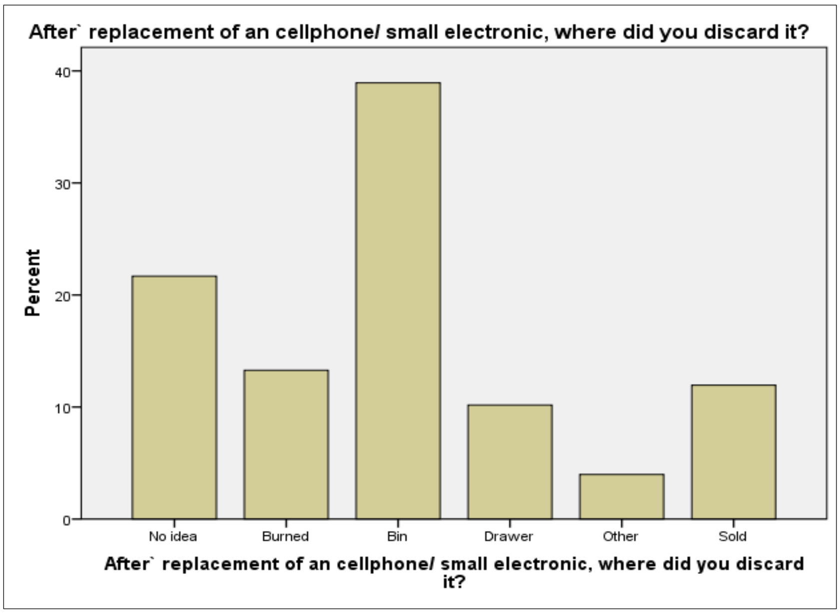

Figure 8 Trends in the disposal and management of e-waste

Findings indicate that a significant portion of small electronics and ICTs was disposed of in trash bins. The data clearly suggested that the bins were non-segregated garbage bins, meaning they contained a variety of home waste materials. This is especially difficult due to the various health and environmental dangers associated with non-segregated waste types. This is due to the fact that, although all garbage is fundamentally waste, distinctions arise based on whether the waste is biodegradable, non-biodegradable, or dangerous. Furthermore, toxicity levels are contingent upon certain waste categories, such as electronic trash, as identified in the literature. Failure to segregate trash diminishes the likelihood of successful management, hence heightening the vulnerability of both persons and the environment to toxins. This reality of e-waste management involves complexity with the identification of well managed e-waste and the degree of dangers associated with these aspects. This data notably underscores the challenges related to e-waste awareness and the efficacy of current waste management methods in Zambia. Nonetheless, the replies from individual participants markedly underscore the deficiencies in Zambia's e-waste management sector. None of the EEE consumers consented to recycling their e-waste in Zambia. Table 6 illustrates the aforementioned.

Table 6 E-waste collection and recycling

Have you physically sent your electronic waste for recycling to any company in Zambia?		**Have any authorities retrieved your electronic waste?**	
0%100%	Yes	0%	Yes
No	No	100%	No

This research indicates a lack of action among EEE consumers and raises inquiries regarding the existence and accessibility of e-waste recycling facilities in Zambia. Research undertaken in Zambia [16, 68] indicates that e-waste management is hindered by inadequate investments and funding, a deficiency of recycling technology, and limited infrastructure, among other issues. These findings align with other regions in Africa, highlighting difficulties in e-waste disposal [69, 70]. Consequently, without e-waste systems, consumers of electrical and electronic equipment may face limitations in their e-waste management methods. I will now examine the e-waste management practices illustrated in this section.

5.3.1. Non-segregation and illicit management practices

According to the data presented herein, e-waste was treated the same as other types of residential waste. As shown in the graph, EEE consumers dispose of e-waste in home dust bins without isolating it from other hazardous and non-hazardous waste kinds. This method has the potential to expose persons and the environment to harmful e-waste components, whether disposed of in landfills or through unregulated means. The data presented in this section show that, while only a tiny number of EEE customers reported burning their e-waste, trash segregation among these consumers is generally low. As evidenced by the data, e-waste is disposed of in the same manner as other non-hazardous residential waste.

The practice of burning home garbage is associated with non-segregation features. Empirically, much e-waste was illegally disposed of and burned. Given the risks involved with e-waste, open burning poses a significant threat to both persons and the environment. Burning emits vapours that behave as pollutants and can travel long distances to expose individuals to harmful substances. For example, open burning plastic coverings for electric lines produces 100 times more dioxins than other non-hazardous household waste. Such e-waste practices in Zambia highlight the global issues about e-waste management. According to the United Nations Environment Programme's (2015) report Waste Crimes, Waste Risks: Gaps and Challenges in the Waste Sector, more than 80% of worldwide e-waste, worth about 19 billion USD, is illegally discarded. However, research demonstrates that unlawful e-waste burning or general disposal increases ambient air contamination caused by PBDEs. This pollutes the air, putting human health at risk [71].

Non-segregation traits among EEE consumers in this setting were also observed in several other countries, including Nigeria and South Africa. For example, research have revealed that e-waste segregation, while crucial, is uncommon in households [72,73, 74, 75]. When hazardous trash, such as most e-waste, is improperly disposed of, it endangers both persons and the environment. Thus, trash segregation is critical, particularly when dealing with potentially hazardous garbage such as electronics.

The data presented in this section indicates that waste segregation among these EEE consumers is typically minimal. Furthermore, e-waste is discarded with other types of non-hazardous residential waste, complicating the issue.

5.4. Influencing factors for e-waste knowledge and management practices

An evaluation of the views and influencing factors in EEE consumer knowledge and practices on e-waste management was carried out among the participants. The results are encapsulated in the table 7 below.

Table 7 Factors that influence e-waste knowledge and management practices

Component	Yes %	No %
Awareness and Knowledge		
I am aware of e-waste	3	97
Cognizant of EEE and electronic waste composition	2.3	97.7
Knowledgeable of the hazards linked to electronic waste	3.8	96.2
Aware of proper management and disposal of e-waste	5.6	94.4
Perspectives and Attitudes towards EEEs/e-waste		
I purchase because I can afford	84	16
I purchase to upgrade	88	12

Untraceable disposal	21.7	78.3
All waste is treated the same	83	17
Perceived Behavioral control		
I am accountable for producing e-waste	75	25
It is my obligation to properly manage my waste	12	88
I manage e-waste to the best of my ability	3	97
Agency/Intention		
I sustainably manage my e-waste	0	100
I acquire EEEs solely when essential	13	87
I desire to manage my waste, although I lack…	95	5
Conversion factors		
Received an education on e-waste	1.4	98.6
Socio-stance	73	27
I feel lazy to separate my waste	59	41
There is no designated area to deposit e-waste	84	16
Limited mechanisms for waste-segregation	96.6	3.4

From the data above, it can deduced that participants exhibited relatively low levels of e-waste knowledge. This was primarily ascribed to insufficient exposure to e-waste and environmental awareness. Although 4% of EEE consumers acknowledged receiving e-waste education, their knowledge primarily stemmed from self-directed research rather than formal instruction on e-waste. The primary channels were broadcast, and social media adverts focused on waste management. Furthermore, even individuals possessing a degree of comprehension regarding e-waste were oblivious to the dangers linked to its inappropriate management. This, in turn, affected their understanding of proper e-waste disposal and management methods. Moreover, even those cognizant of e-waste-related hazards did not implement suitable e-waste management procedures. This study indicates that awareness of e-waste influenced its management at both individual and household levels. Nonetheless, this was additionally affected by many conversion factors that complicate e-waste management. Evidently, this study's findings are indicative of substantial knowledge deficiencies among EEE customers in this context, along with constraints in obtaining e-waste information. This reality is shaped by many factors. I succinctly address these conversion factors in the subsequent section.

5.5. Conversion factors that influence the knowledge and practices on e-waste among EEE consumers

5.5.1. Personal conversion factors: Self-eco identity and perceived value of EEEs

The acquisition, utilization, and management of EEEs and e-waste were predominantly associated with individuals' perceptions of environmental conservation. Nonetheless, their self-eco identities were not the sole determinants of their EEE consumption and e-waste management. Human interactions with the environment are predominantly influenced by one's self-perception in respect to the biophysical environment. It encompasses an evolved feeling of connection individuals possess with the natural environment, hence influencing their behaviour, priorities, and values concerning the environment [76]. The knowledge one possesses regarding a specific element has the capacity to alter their conduct. Nevertheless, the data indicates that the acquisition of e-waste knowledge was insufficient, hence constraining the development of environmental responsibility in regard to e-waste management.

The research indicates that individuals acquire EEEs to conform to societal trends and expectations, driven by a perceived necessity for upgrading. The inference is that the production of e-waste escalates alongside the heightened desire for electronic enhancements. Although a significant portion of EEEs is not discarded, the increasing demand for new electronics results in a rise in the quantity of EEEs circulating in the market, hence contributing to e-waste within a short time.

5.5.2. E-waste knowledge asymmetry and insufficient e-waste management mechanisms

The lack of e-waste knowledge suggests that the distribution of information regarding e-waste in Zambia is inconsistent or non-existent. This can be ascribed to the absence or inadequacy of e-waste awareness campaigns. The findings of this study suggest that the proficient management of e-waste is significantly affected by an individual's understanding of its hazardous components and their implications for human health and the environment. Consequently, the less individuals comprehend the risks linked to e-waste, the more they participate in unsustainable e-waste management techniques. The absence of sustainable alternatives and effective methods for managing e-waste hinders sustainable practices in e-waste management. In instances where EEE consumers exhibited a readiness to sustainably manage their locally produced e-waste, the absence of effective methods and supportive frameworks hindered their efforts. This requires enhancing technology and mechanisms for regulating and managing electronic waste.

5.6. Recommendations and implications for policy and practice

This study is important for evaluating the imperatives for effective management of electronic waste in developing counties like Zambia and beyond. The results of this study illustrate the complexity involved in effectively managing e-waste among consumers of EEEs. Data indicates that various factors contribute to the acquisition and utilization of EEEs, resulting in varying origins and generation rates of e-waste. Moreover, a correlation exists between knowledge regarding e-waste and management practices. Nonetheless, even when there is both knowledge and the will to handle e-waste sustainably, numerous conversion factors affect this implementation. Consequently, the successful development of procedures for e-waste addresses the many difficulties presented in this context. The subsequent actions should be emphasized to reconcile the disparity between awareness of e-waste and the consumption of EEEs. Furthermore, it is essential to address the practical deficiencies related to EEE importation, consumption, e-waste creation, and e-waste management in Zambia. I recommend the following:

5.6.1. Enhance e-waste education

E-waste education should be prioritized in Zambia through both official and informal methods. This can be accomplished through environmental education and awareness initiatives designed to empower communities with knowledge regarding e-waste. Through e-waste education, consumers of electrical and electronic equipment can cultivate a sense of stewardship and accountability towards the environment. An enhanced comprehension of the dangers linked to e-waste can encourage customers to adopt environmentally conscious actions regarding the acquisition, use of electrical and electronic equipment, and the disposal of e-waste.

5.6.2. Introduce inventories and buybacks to trade obsolete EEEs

Inventories are essential for tracking, assessing, and quantifying electrical and electronic equipment (EEE) and the potential build-up of e-waste. This enables the tracking of the movement and circulation of EEEs, thereby facilitating the mapping of e-waste in Zambia. The identification of specific material composition of EEEs can significantly enhance knowledge and planning for successful e-waste management procedures. The dangers posed by e-waste, including lead and mercury that may build and seep into the environment, can be mitigated by keeping e-waste from entering landfills. Furthermore, e-waste management can be enhanced by implementing and funding buy-back initiatives. These policies and initiatives can facilitate effective e-waste management, resource conservation, and yield economic advantages for the nation. By enhancing programs and opportunities for buy-backs in Zambia, EEE consumers can exchange their outmoded electrical and electronic equipment, hence facilitating the regulation and management of e-waste. Buy-backs can be enhanced by establishing recycling operations of varying scales. Such activities can enhance the circulation of e-waste materials within the Zambian environment and expand employment prospects for recyclers. Particular enterprises should establish supportive procedures for buy-backs that enable device owners to receive a nominal sum for their obsolete electrical and electronic equipment (EEE). For instance, several regions globally promote buy-backs as a substitute for electronic waste management. For instance, enterprises in New York and California acquire obsolete devices for recycling purposes. Companies such as Gazelle are established enterprises that focus on repurchasing used mobile devices. These projects are also gaining traction across the African continent. The South group recycling in South Africa acquires e-waste from consumers for recycling purposes. Such initiatives can facilitate the regulation of e-waste management. Consequently, Zambia ought to prioritize the implementation and installation of buy-back and other recycling initiatives as a viable response to electronic waste. In this manner, EEE consumers can reduce the necessity of establishing phone 'graveyards' in their residences and other unsustainable electronic waste management techniques in Zambia.

5.6.3. Legal frameworks on e-waste recycling

Despite the implementation of the Environmental Management Act (EMA) No. 8 of 2023 in Zambia, the regulations and management of e-waste are inadequately addressed. Furthermore, the Electronic Communications and Transactions Act of 2021 and the Solid Waste Regulation and Management Act of 2018, referenced by the EMA, merely define e-waste as various types of electrical and electronic equipment that have lost value to their users or no longer fulfil their intended purpose, without offering specific guidelines for its regulation and management. The classification of hazardous waste does not specifically encompass e-waste. Essentially, these legislative papers inadequately delineate standards for the management of electronic waste disposal. Consequently, norms for importation, collection, disposal, and treatment must be explicitly defined. This is essential for the efficient management of rapidly increasing e-waste.

6. Conclusion

This paper demonstrates that numerous factors affect the consumption of electrical and electronic equipment (EEEs) and subsequently the production of e-waste. Planned obsolescence, wherein electronic gadgets are designed for replacement, exacerbates the accumulation of e-waste in developing nations such as Zambia. This data suggests that in the global corporate sector, electronics are designed to operate for a specific duration, after which they become obsolete. A significant portion of these electronics is sent to underdeveloped nations such as Zambia, which lack the necessary capabilities to properly manage the outmoded products, resulting in e-waste. Additional factors affecting the utilization of EEEs and the production of e-waste encompass consumer traits and their awareness of e-waste. This research demonstrates that, despite the rising use of electronic devices, there is a significant lack of understanding regarding the content and dangers of e-waste. Data indicates an association between understanding of e-waste and attitudes regarding its acquisition, use, and disposal. Consequently, information and education regarding e-waste must be prioritized in response to the e-waste crisis.

The e-waste dilemma is further intensified by additional variables, including inadequate e-waste management systems and deficient legal frameworks regarding electrical and electronic equipment and e-waste legislation. This study has emphasized the dynamics of EEE usage, e-waste generation, and e-waste management strategies. Evidently, e-waste disposed of in landfills leads to considerable environmental degradation and presents hazards to human health. Moreover, the predominant scavengers in Zambia are inadequately trained in hazardous e-waste management, thereby heightening their exposure risk. However, e-waste remaining in homes and outdoor environments further exacerbates environmental degradation, pollution, and increased human health risks. It is essential to contend that tackling the e-waste issue in Zambia must consider the opportunities for consumers of electrical and electronic equipment to be informed about e-waste and the options for its appropriate management. The implication is that, in the absence of environmentally informed potential EEE consumers and effective, e-waste management mechanisms, dealing with the dark side of the technological age will be more burdensome rather than beneficial for growing economies like Zambia. Therefore, this paper stresses the need for the enhancement of e-waste education; the formulation of e-waste regulatory frameworks; the establishment of inventories, strengthening avenues for e-waste buyback schemes and re-evaluation of existing e-waste management facilities in the country.

Compliance with ethical standards

Disclosure of conflict of interest

I Daizy Shoma Nalwamba declare that there are no conflicts of interest related to the authorship or publication of this research article.

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