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Appraisal of Households' Knowledge and Perception towards E-Waste Management in Limpopo Province, South Africa

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Abstract: The generation of electronic waste (e-waste) is increasing at an alarming rate in South Africa. This waste stream is also emanating from household appliances due to beneficial attributes accrued to the use of these electronic devices. At the same time, these devices are a source of concern considering the environmental impacts as well the threat of health hazards they possess to human wellbeing. In appraising household knowledge and perception on e-waste management in Limpopo Province of South Africa, 200 semi-structured, self-administered questionnaires were used in eliciting data from the participants. The results indicated that 76% of the respondents believed that e-waste streams have negatively affected their environment. Additionally, 85% of the survey households are willing to pay for the proper disposal of their e-waste. Furthermore, the results indicated a statistically significance between gender and knowledge on e-waste management (p-value 0.003) while there was no statistically significant difference between gender and perception (p-value 0.318) on e-waste management. Based on the results, the study recommends awareness and educational campaigns as a step in changing the perception of households on e-waste and environmental consciousness.

Keywords: e-waste; environmental problems; households; South Africa; waste disposal; waste management

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1. Introduction

Globally, in the last two decades, waste electrical and electronic equipment (WEEE), also referred to as e-waste, has created a new environmental challenge [1,2]. Due to rapid innovation and a decrease in the costs of production together with the accrued benefits, there has been a tremendous increase in access to electronic devices and digital technology. The unanticipated repercussion of this is a distending of electronic waste (e-waste) [2]. It is estimated that only 20% of the global e-waste produced in 2018 was documented, collected and recycled. Worldwide, the generation of e-waste has been on the increase and it was estimated that approximately 54 million metric tons of e-waste were produced in 2019 [3]. Relying on an annual growth rate of about 4 to 5%, e-waste is regarded as one of the fastest-growing waste streams in the world [4].

The commonly accepted definition of e-waste is anything that runs on electricity. It covers a broader segment of discarded electrical devices ranging from items that include household appliances such as ovens, televisions, computers, monitors, laptops, mobile phones, and toasters [5,6]. Also within the category of e-waste are telecommunications and information technology equipment, medical devices, automatic dispensers, lighting equipment such as bulbs, batteries, spent fluorescent tubes, light-emitting diodes (LED), consumer electronics such as battery-operated toys, smoke alarm, microwaves, printers,

coffeemakers, electrical toothbrushes, washing machines, and sport and leisure equipment [7,8]. Others classified as e-waste include cathode-ray tubes, fridges, internet routers, activated glasses, lead capacitors, end-of-life vehicles, plastic casting and printed circuit boards [9,10].

Largely due to the substance component that makes up these devices, e-wastes are regarded as problematic because of the toxic contents, which if mishandled and improperly discarded can be detrimental to human health and also lead to environmental pollution and degradation. Indicated by different studies, is the association between e-waste streams and different health hazards, which poses potential human and environmental threats, thereby creating a management challenge in most societies and communities [11–14]. In most developing countries, the severity and significance of managing e-waste are high, particularly in countries where the proper processes on waste management systems and policies are lacking in regulating the waste streams as well as efficient and effective infrastructures to manage it [15]. Many households in the society who play a major role as stakeholders in the generation of these waste streams are affected by the waste management system, hence the appropriation, utilization, disposal, and recycling of e-waste is of paramount concern [6,16]. In the disposal of e-waste, households are confronted with serious challenges compared to industrial enterprises and other institutions owing to measures of unawareness in handling the waste stream [6,11,16]. A significant component that influences the decision of households regarding the handling of such waste is the extent to which the household is informed and aware of the numerous problems associated with e-waste [13,14,17].

This exploratory paper, therefore, aims at appraising the fundamental knowledge and perception of e-waste management at the household level in the Limpopo Province, South Africa. To get a better understanding of the objective, the vital questions assumed are types of electronic devices owned and used by the households; willingness among the households to participate in e-waste management streams; and methods used in discarding e-waste in the province. The study is grounded on the hypothesis that households' willingness to participate in e-waste management is dependent on knowledge, perception levels as well as socio-economic and demographic factors.

2. Literature Review

2.1. E-Waste Categories in South Africa

The definition of e-waste in South Africa is adopted from the directive of the European Union Waste Electronic and Electrical Equipment. WEEE is regarded as "all electronic and electrical equipment that has come to the end of its life and can no longer be used for its originally intended purpose" [18]. The e-Waste Association of South Africa (eWASA), was created in 2008 with the mandate to "manage the establishment of a suitable environmentally sound e-waste management system for the country." Together with other several organizations in the collection of e-waste, eWASA is making the responsible treatment and disposal of e-waste easier. The South Africa E-waste Industry Management Plan (2019–2024) categorized e-waste into 10 classes as presented in Table 1.

Table 1. South Africa e-waste categories [18].

1. Large household appliances
2. Small household appliances
3. Information Technology and telecommunications equipment
4. Consumer equipment and photovoltaic panels
5. Lighting equipment
6. Electrical and electronic tools (with the exception of large-scale stationary industrial tools)
7. Toys, leisure, and sports equipment
8. Medical devices (with the exception of all implanted and infected products)
9. Monitoring and control instruments
10. Automated dispensers

2.2. European Union Directive on E-Waste

Consisted in e-waste systems are interdependent components that together manage the stream of e-waste from the disposal point to where the materials are extracted through recycling processes. The process is categorized into three stages, namely: Collection, pre-treatment, treatment, and disposal [19]. The collection, treatment and disposal are critical elements in the management of e-waste. In most developed countries, there is the existence of framed convention, directives, and laws designed at nurturing the appropriate collection, treatment, and recycling of electronic waste including the safe disposal of non-recyclable components [20]. These include product stewardship, extended producer responsibility (EPR), advance recycling fund (ARF), and the initiative of the 3Rs: Reduce, reuse, and recycle. In an effort to reduce the amount of waste that ends up in landfill sites, the European Union promulgated two directives on the management of e-waste.

The first principle places an obligation on the producers of e-goods to take back end-of-life or waste products at no charges through EPR [21]. The second relates to the polluter pay principle (PPP), which supports the notion that the one responsible for waste has to pay the cost of handling the waste in a proper manner [22]. Although, the principle of the EPR allows for the manufacturers to delegate the operational end-of-life (EOL) treatment to a third party, thus creating the emergence of a new organization known as the producer responsibility organization (PRO). There is a variation on how the PRO is organized because the national translation of the WEEE directive differs from country to country [23,24].

The WEEE directive through the EPR which allows for PRO has been a successful implementation in the management of e-waste in Switzerland [25]. Whereas, in Italy according to a study by Isernia et al. [26], the results indicated that at the national level, the Italian organization for the management of WEEE and the related legislation has not been so effective in supporting and achieving the EU WEEE collection targets but the feat was recorded in some geographical areas and provinces which outperform the EU targets. Therefore, based on the results, organizations of the Italian WEEE collection system will play a vital role if guided by more awareness drive [26]. Nonetheless, in many developing and transition countries, the treatment of e-waste is backyard operations whereby cyanide leaching, open sky incineration, and simple smelters to recover valuable metals with fairly low yields and the rest are discarded with municipal waste at open dumps, regulated and unregulated landfill sites as well as in water bodies [27], thereby creating adverse environmental and human health effects.

2.3. E-Waste Management in South Africa

There is no specific and exclusive legislation relating to the management of e-waste in South Africa yet, but there are elements in the existing legal framework that regulates directly or indirectly certain aspects of e-waste management in the country [18]. There are more than a few statutes that can be applied in the handling, treatment and disposal of e-waste in the country. Government policies and legislations that are imperative in regulating aspects of South Africa e-waste include the Constitution of the Republic of South Africa, The National Environmental Management Act 107 of 1998, Waste Management Act, 2008 (Act No.59 of 2014), Waste Amendment Act, 2008 (Act No. 26 of 2014), Second Hand Goods Act, Allied Policy Regulations, Hazardous Substances Act (Act No 5 of 1973), Health Act (Act No. 63 of 1977), Environment Conservation Act (Act No. 73 of 1989), Occupational Health Safety Act (Act No. 85 of 1993), National Water Act (Act No. 36 of 1998), Municipal Structures Act (Act No. 117 of 1998), Municipal Systems Act (Act No. 32 of 2000), Mineral and Petroleum Resource Development Act (Act No. 28 of 2002), Air Quality Impact Act (Act No. 39 of 2004), SAWIC Waste Policy and Regulations and Waste Management Licences Required—Section 20(b) of NEMWA 59 of 2008. Also, South Africa is a signatory member of the international context and policy of Restriction of Hazardous Substances (RoHS), WEEE Directive and the Basel Convention [18].

Regrettably, there is an increasing accumulation of large quantities of e-waste in several households and offices as the devices become archaic and no longer function optimally, thereby creating storage and problems of disposal [28,29]. In urban areas of most African household, there is at least one item of electronic product ranging from cell phone and computer to a relatively large appliance such as televisions, refrigerators, and washing machines. When these electrical equipment are purchased, consumers are rarely provided with information on the handling and properly disposing of the equipment after their lifespan, thus creating ineffective e-waste management [30]. Often, these wastes are indefinitely stored with a view of disposing of them in the future [31]. These trends of inappropriate e-waste disposal then pose negative environmental impacts and public health risks in many African and developing countries which are further heightened by the near nonexistence of community waste collection methods and recycling amenities [32–34]. Thus, knowledge of e-waste has been raised in several studies towards the effective management of this waste stream [18,32,35–37]. Among stakeholders and households, the methods of disposing of e-waste are largely a function of knowledge and perception. Accentuated by Wang et al. [38], "environmental awareness, attitude towards recycling, perception of informal recycling, income and cost of recycling, norms and publicity indirectly affects residents' behavior and intention towards e-waste recycling by way of intervening variable, whereas, perceptions of informal recycling, norms, and publicity have a positive impact on e-waste.

However, in most developing countries, at household levels, there is a low safety measure and public awareness regarding the applicable management of e-waste. Knowledge and attitude studies on e-waste in countries of the global south revealed that there is a direct relationship between awareness and the willingness to recycle e-waste which is seen as a paramount position for efficient and effective e-waste management [39–41]. Also, some developing countries such as India, Vietnam, and Bangladesh have demonstrated ineffective e-waste recycling efforts as a sizeable percentage of their population are to some extent unaware of the cautionary processes needed for handling and disposal of e-waste [39,40,42]. Also pointed out in the literature, most households are willing to pay for an effective e-waste disposal measure [41,43].

E-waste is growing three times faster than the rate of solid waste in South Africa [44]. E-waste accounts for nearly 8% of the total waste and about 2–3% of materials disposed of in the country's landfill [18]. It is estimated that each individual in the country generates about 6.2 kg of e-waste, while about 360,000 tons of e-waste is generated annually with only 12% recycled according to the Department of Environmental Affairs [45]. Contained in the national policy and media circles, e-waste is depicted as offering both threats and opportunities. As a threat, e-waste is expressed as a contamination source to the environment, arising from improper handling and treatment where significant quantities are routinely discarded [46–48]. Potentially, a non-negligible amount of toxic substances such as mercury, flame retardants, cadmium, lead, or polychlorinated biphenyls (PCBs) are enormous in e-waste devices and poses environmental health risk through inhalation of poisonous fumes as well as chemical accumulations in food, water and soil [49]. Furthermore, cardiovascular and pulmonary diseases and illness as well as neurological and respiratory ailments may be aggravated through exposure to hazardous materials emanating from e-waste streams [49]. Of note, while technology is utilized in the processing of e-waste in the country, it is neither state-of-the-art nor uniform. More advanced processing is done out of the country as most small and medium-sized firms (SMEs) concentrate on early-stage value chain processing [47].

To a fair extent, the recycling industry in South Africa can be considered as established because the rates of collection for paper and tin-plate steel cans at 52% and 63% respectively is steadily growing [50]. It has been observed in South Africa that most obsolete electronic devices are typically stored and never reaches the waste stream [50]. The economic value that could be derived from e-waste is lost due to poor formal collection rate and also creating potential environmental consequences that could lead to illegal processing of e-waste from informal collection. It has been found that most obsolete electronics in South Africa

are simply stored and never enter the waste stream [50]. These poor formal collection rates result in economic value not being derived from e-waste, and also potentially have environmental consequences, including informal collection that can result in the illegal processing of e-waste. Although e-waste studies have been conducted in South Africa [47–49,51], at the household level, there are still limited studies on e-waste streams, hence there is the need for a more all-inclusiveness to help understand the knowledge and perception of e-waste in the country.

3. Materials and Methods

3.1. Description of the Study Area

Figure 1 shows the map of South Africa indicating the location of the study area. Limpopo Province lies between coordinates 23°40′13.81″ S and 29°41′79.90″ E. It is the northern-most province of South Africa, lying within the curves of the great Limpopo River [52]. The province shares international borders with Botswana to the west, Zimbabwe to the north, and Mozambique to the east. With its shared borders, the province is regarded as the gateway to the rest of Southern Africa, making it economically favorable to other southern parts of the Africa continent. Limpopo Province covers a total land area of 125,755 square kilometers and has a population of about 5.98 million people comprising 2,828,873 males and 3,153,712 females, thus representing 12% of the national population of South Africa [52]. The province is composed of five administrative district municipalities namely: Capricorn, Mopani, Vhembe, Waterberg, and Sekhukhune Districts. The demographics consist of several ethnic groups which are distinguished by culture, race, and language. The province is experiencing an increase in urban population with an average density of 45.5 per square kilometer. The urban population grew from around 807,000 in 2007 to over 1,100,000 in 2016. Also, the share of households occupying formal dwellings increased from 81% in 2004 to 90% in 2016. The economy of the province has managed to sustain a positive growth of 1.2% in 2017, which was a recovery from the 2016 negative growth rate of 1.6%, with a positive outlook moving forward [52]. The pocket of unemployment and income inequality are consequences of a myriad of issues varying from low economic growth and petty wages levels. Although pronounced development in the economy and standard of living has increased in recent times, it is still low compared to the national average [53]. The province was selected for this survey principally because of the accelerated urbanization pace and increasing population density. There are pockets of existing landfill sites, yet the province is also enmeshed in the burden of waste management [54,55]. Furthermore, the province is a host to two comprehensive universities, several satellite campuses of other universities, a growing and large numbers of technical and vocational education and training (TVET) institutions, hence compelling the need for empirical research of this nature to offer solutions to the environmental challenges faced in the province.

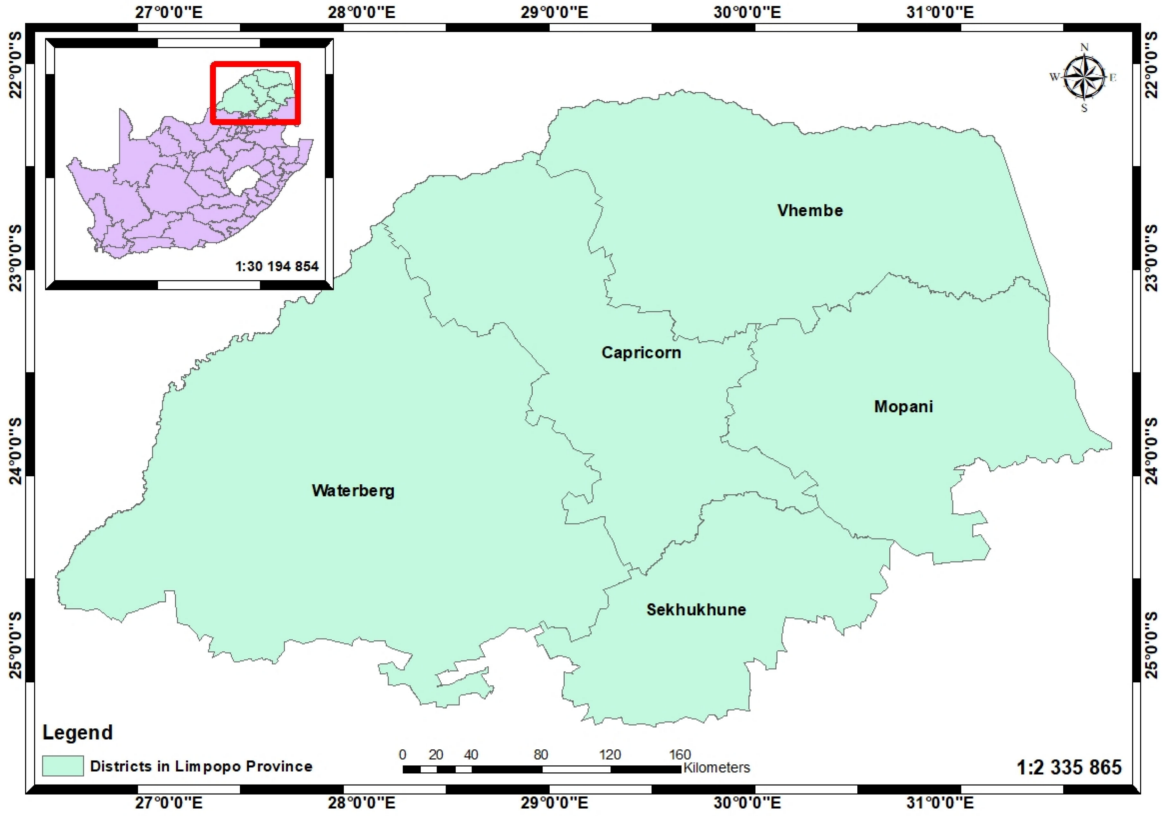

Figure 1. Map of South Africa showing the study area.

3.2. Sampling Method and Data Collection

This study adopts a descriptive research design approach and a principle of simple random sampling method which is intended to provide statistical representation and data reliability. Participation in the study was solely voluntary and an informed consent form was signed before data collection. Questionnaires were pre-tested before the main survey with adjustments and corrections made based on the responses to improve clarity. A total of 200 questionnaires were used in eliciting data from the respondents which were self-administered, semi-structured and divided into four sections. Related to other e-waste related surveys [15,32,37], household heads were targeted as respondents. In a household that refused to participate, another household was randomly drawn into the sample. Section A entails demographic and socio-economic characteristics information including gender, age, marital status, educational level, income earned, and household size. Section B pertains to knowledge and perception regarding e-waste. Section C entails motives for changing electronic merchandises. Section D dwells on environmental problems allied with e-waste management. For convenience and simplicity, the questionnaires were administered in English language and, where indispensable, interpreters were used in local dialects. Trained research assistants from the University of Venda were engaged to execute and oversee the administration of the questionnaires, which was thoroughly monitored for data quality assurance.

3.3. Data Analysis

Data cleansing and statistical analysis were carried out using Statistical Package for Social Sciences (SPSS) version 24 developed by International Business Machine (Armonk, NY, USA). Descriptive statistics were applied in analyzing the socio-demographics of the respondents captured data. The Analysis of variance (ANOVA) was used to compare the association difference between two or more independent groups, while differences in numerical variables

were determined using the *t*-test. The level of statistical significance of 0.05 was considered. The results are presented by using tables and other statistical illustrations.

3.4. Ethical Clearance

This study was approved by the Ethical Committee of the University of Venda (certificate number: SES/16/GGIS/05/1511). To ascertain the avoidance of harm to the participants, informed consents of the participants were obtained before the commencement of the study. Where necessary, permissions were obtained from the appropriate government/traditional authorities.

4. Results and Discussion

4.1. Demographic and Socio-Economic Profile of the Respondents

The demographic characteristics of the respondents as presented in Table 2 indicated that there were 65.5% males (n = 131) and 34.5% females (n = 69). The higher number of male respondents was because that they are regarded as household heads and the questions were directed to them. This does not reflect that there are more males in the study areas than females. The reason why there were female respondents is that the males who are regarded as the household heads were not available at the time of administering the questionnaires, hence the questions were directed to the females who acted as the household head. The majority of the respondents were within the age group of 41–50 years, representing 44.5% of the total sample, while the lowest age bracket was within the less than 25 age group at 5.5%. The marital status indicated that 13% (n = 26) of the respondents were single, 77.5% (n = 155) were married while 5% (n = 10) and 3.5% (n = 7) were divorced and widowed respectively. Educational level indicated that 87% of the respondents attain secondary school education, while the lowest level was recorded for those without any formal education at 3.5% (n = 7).

Table 2. Demographic characteristics of respondents in the study.

Variable	Frequency (N)	Percentage (%)
Gender		
Male	131	65.5%
Female	69	34.5%
Total	200	100
Age (Years in bracket)		
Less than 25	11	5.5%
25–30	27	13.5%
31–40	32	16%
41–50	89	44.5%
51 and above	40	20%
Did not tell	1	0.5%
Total	200	100
Marital status		
Single	26	13%
Married	155	77.5%
Divorced	10	5%
Widow/widower	7	3.5%
Did not tell	2	1%
Total	200	100

Table 2. *Cont.*

Variable	Frequency (N)	Percentage (%)
Highest level of education		
No formal education	7	3.5%
Primary	19	9.5%
Secondary	87	43.5%
Basic degree	54	27%
Honours degree and above	33	16.5%
Total	200	100

Presented in Table 3 are the socio-economic characteristics of the survey. The occupational outcome revealed that 38% of the respondents are engaged in the civil service sector of different government parastatals, followed by those in the trading sector at 26%. Years of employment as a socio-economic factor denote that 57.5% have been employed in less than 10 years, while 15.5% have been employed for over 31 years. Income earned revealed that 37.5% earn between R3501 to R5000 monthly, while 21.5% of the respondents earned above R10000. With regards to household size, 59.5 (n = 119) of the respondents indicated a family unit between 2–4 persons in the household, while the least family unit was recorded at 2% (n = 8) for a person staying alone.

Table 3. Socio-economic characteristics of the survey.

Variable	Group	Frequency (N)	Percentage (%)
Occupation			
	Civil service	76	38%
	Farming	24	12%
	Trading	52	26%
	Mining	21	10.5%
	Student	14	7%
	Others	13	6.5%
Total		200	100
Years of Employment			
	Less than 10 years	115	57.5%
	11 to 30	54	27%
	31 and above	31	15.5%
Total		200	100
* Income (Monthly)			
	Less than R3500	18	9%
	R3501–R5000	75	37.5%
	R5001 to R10000	64	32%
	R10001 and above	43	21.5%
Total		200	100
Household size			
	1	8	2%
	2–4	119	59.5%
	5–6	57	28.5%
	7 and above	16	8%
Total		200	100

* 1USD equals R15.9.

4.2. E-Waste Knowledge and Perception

Depicted in Figure 2 are the percentages of the different electronic devices used and owned by members of the surveyed households. Cell/mobile phone and televisions at 96% and 86% respectively were mentioned as the most owned devices. In today's world, cell and mobile phones are some of the most universal and essential devices owned by several households even in low-income economies [56,57]. Additionally, other devices such as laptops (58%), refrigerators (78%), radio/media players (74%), microwaves (76%), and kitchen appliances (92%) were reported by the respondents as electronic devices owned. According to Nethaji-Mariappan et al. [34], in a study in India, the purchase of electronic devices can be attributed to income earned and increasing economic growth. However, regardless of the electronic type acquired, these devices at some point reach the end of their lifespan, thereby requiring disposal.

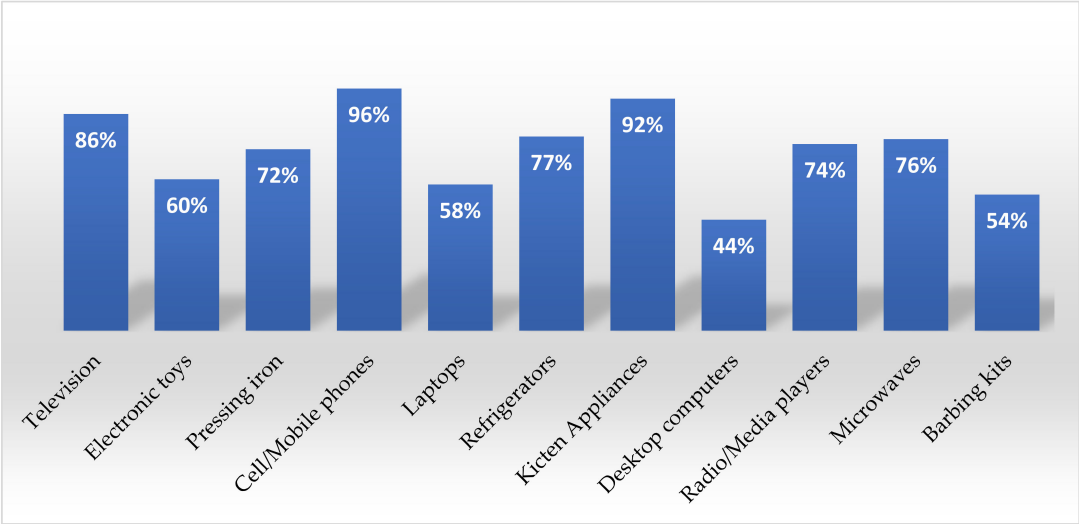

Figure 2. Percentage of some of the electronic devices owned by households in the survey.

Revealed in Table 4 is the knowledge and perception assessment of e-waste in the survey. From the evaluation questions, 70% claimed to know about e-waste as against 18% of the respondents that assume no knowledge. Similarly, 74% claimed to have knowledge of the associated health risks and e-waste, whereas 18% claim to not know the hearth risk and e-waste. On the improper disposal of e-waste, 76% of the respondents indicated that improperly discarded e-waste poses environmental threats, while 20% revealed otherwise. The management of e-waste is embedded in knowledge, perception as well as thorough e-waste education, which oftentimes, is lacking in many developing countries such as in South Africa, where institutional supports and resources are limited in the diffusion of appropriate measures in discarding e-waste [43,49,58]. Notwithstanding the limitations as regards e-waste, an overwhelming majority of the respondents at 94% agreed that sorting e-waste is very integral in the management of waste in the province.

Table 4. Statements on e-waste knowledge and perception by the respondents.

Statement	Yes	No	Maybe
Do you know what e-wastes or electronic wastes are?	70%	18%	12%
Do you think that e-wastes requires treatment before disposal?	66%	24%	10%
Do you think that improper disposal of e-waste is harmful to the environment?	76%	20%	4%
Do you know that aware that e-waste contains harmful substances?	62%	26%	12%
Are you aware of the associated health risks of e-waste?	74%	18%	8%
Do you consider your household to be environmentally conscious?	58%	22%	20%
Have you been ever educated on e-wastes?	52%	42%	6%
Do you think it is important to sort e-wastes as a measure of waste management improvement?	94%	4%	2%

The results presented in Figure 3 defines the different sources of knowledge regarding e-waste at the household level in the province. Fairly, most of the knowledge information about e-waste as cited by 34% of the respondents, got the information from the workplace/office. Television and radio sources accounted for 20%. E-waste source of information from schools accounted for 32%. Other sources of knowledge about e-waste as revealed by the respondents indicates that newspapers/magazines account for 12%, social media 15%, and community/family members at 28%. Dishearteningly, 35% of the respondents from the survey revealed that they do not know about e-waste, hence, signifying the low level of knowledge and awareness dissemination about the waste stream.

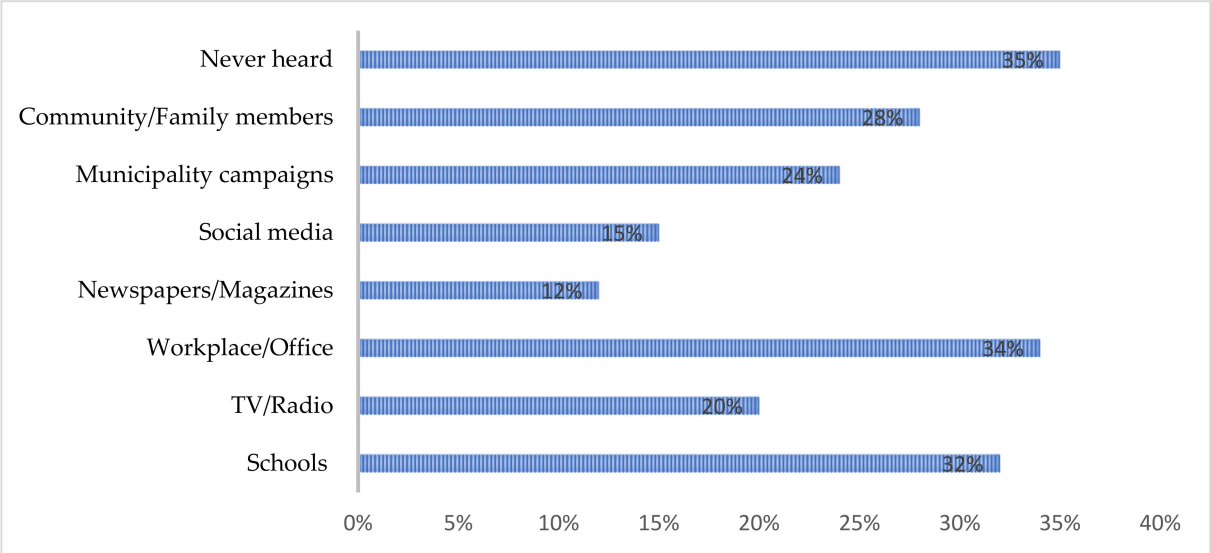

Figure 3. E-waste information sources from the household survey.

4.3. Motives for Changing Electronic Devices

Different motives have been reported as to why new electronic devices are being purchased or acquired as summarized in Figure 4. Strongly agreed by the respondents at 38% is that they change their devices due to damages/non-functionality. Sixteen percent attributed changing their devices due to new designs and upgrades, 24% acquire new electronic devices as a result of theft, while 22% signifies social pressure as the cause of procuring new devices. The concept of social identity in acquiring electronic devices is the perceived utility by the association of a social group, peer and pressure influence to use these devices [59]. The consumer is motivated by social affiliation to behave in the same manner as that of their social class [60]. Consumers preferably purchase brands that represent their social status [61].

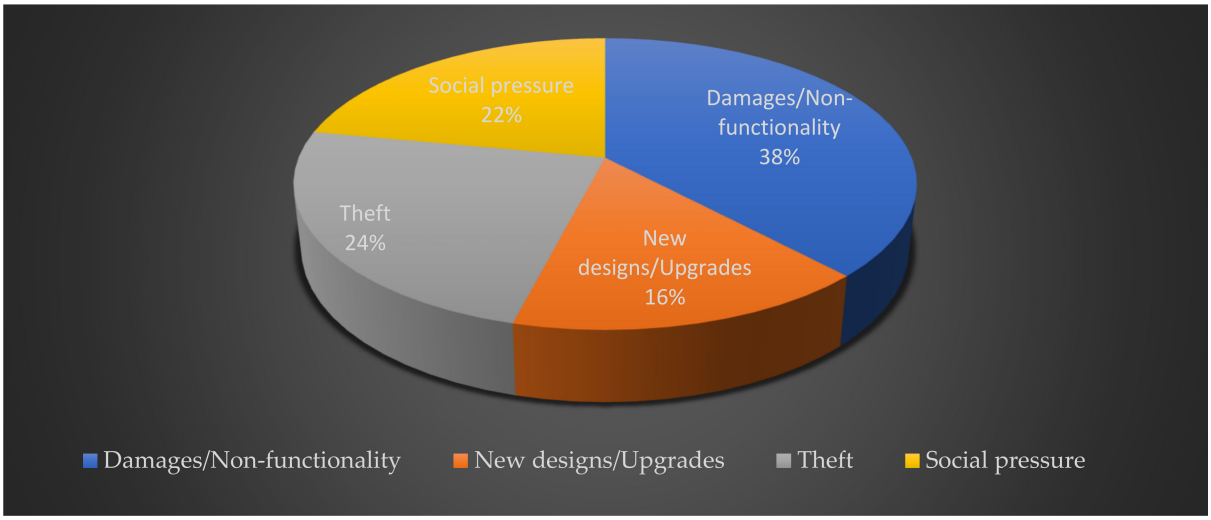

Figure 4. Respondents' reasons for changing electronic devices.

Illustrated in Figure 5 are the various methods employed by the households in disposing of e-waste in the study area. The leading method as indicated by the respondents at 41% is discarding their e-waste in the general waste/garbage bins. Waste/garbage bins were also reported by Tshimbana and Tekere [55] as the most adopted disposal method. The next most used methods at 23% by the households is storing these e-wastes at home as a backup. This could be attributed to the absence of e-waste door-to-door collectors in the province. Owing to the lack of feasible options, soring e-waste at home has also been reported by other studies [30,62]. Other methods indicated by the respondents include donations to charities, families and friends for re-use at 13%, sell in classified adverts and to individuals at 9%. The summation of donating to charities, families and friends for re-use, selling to an individual or classified adverts and selling to recyclers (32%) extends the life cycle of the electronic devices, thus providing a reduction in the e-waste stream.

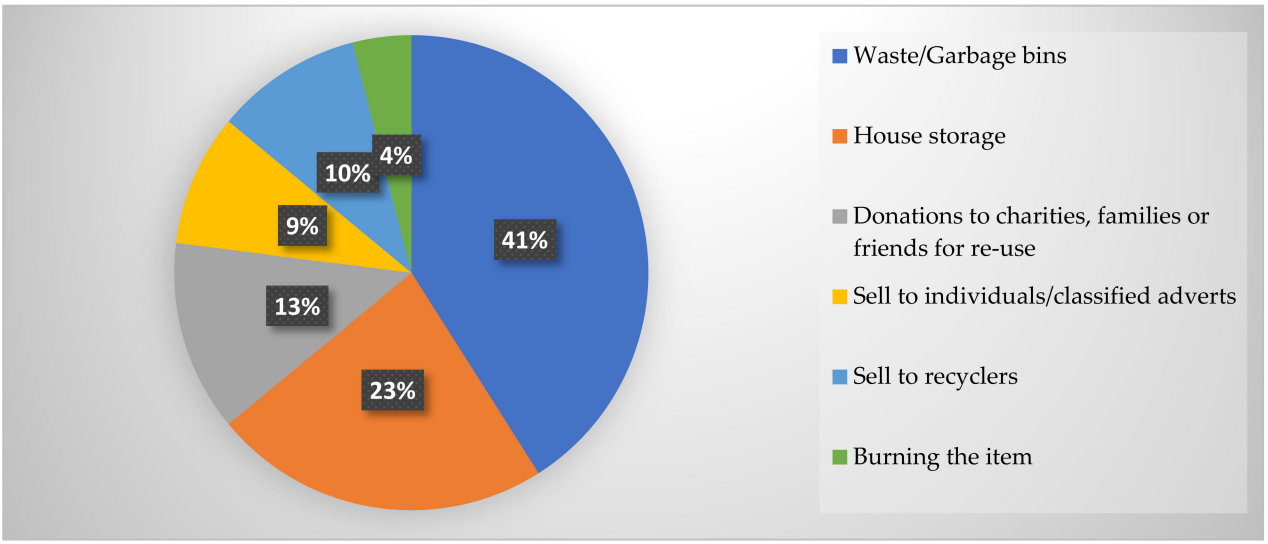

Figure 5. E-waste disposal methods by respondents.

4.4. Environmental Problems Connected with E-Waste Management

In Figure 6, the surveyed results indicated that with regards to environmental problems connected to e-waste, 40% of the respondents agreed that e-waste could be a source of diseases, while 28% strongly agreed. A total of 8% indicated their neutrality, while 14% and 10% disagreed and strongly disagreed respectively. For atmospheric emissions as a source of environmental problems, 36% of the respondents agreed, 22% strongly agreed to the statement, 10% of the respondents were neutral, 20% strongly disagreed, and 12% strongly agreed. For eyesore, 38% of the respondents agreed on the view that improper disposal of e-waste is a concern for environmental problems. Also, 30% strongly agreed to the statement, 10% indicated neutrality, 12% disagreed, and 10% strongly agreed.

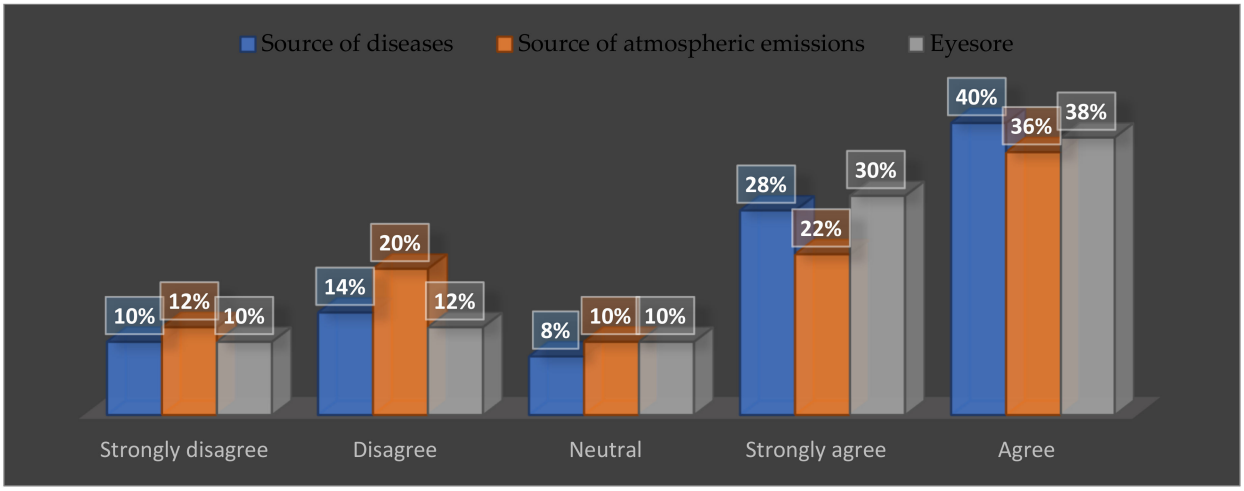

Figure 6. Environmental problems associated with e-waste.

4.5. Willingness of Households' Participation in Waste Management

In determining household willingness to participate in waste management, different statements were used in evaluating their perception in the survey. As presented in Table 5, the majority of the households at 85% are willing to participate by paying for proper e-waste disposal method. Payment for e-waste disposal could be a source of revenue generation for the province based on the commitment level and the willingness of the households to pay. The province could provide drop-off facilities that can act as a collection point for these waste streams and thus improve recycling effectiveness. This study corroborates the study by Miner et al. [15] regarding the study of households' awareness and willingness to participate in e-waste management in Jos, Nigeria. There a is need for more and proper education vis-à-vis knowledge and perception levels of e-waste management in the province together with other soft measures such as communication and awareness campaigns. More so, at 84%, respondents indicated that the extended responsibility policy could help manage the waste streams from e-waste in a more efficient manner by providing more effective measures in disposing of e-waste.

Table 5. Respondents' willingness to participate in e-waste management.

Statement	Yes	No	Maybe
Would you welcome more education regarding e-waste?	80%	15%	5%
Are you willing to pay for effective e-waste disposal?	85%	12%	3%
Would a programme like Extended Producer Responsibility (EPR) help in managing e-waste better?	90%	8%	2%
If yes, would you want to participate in the programme?	92%	6%	2%

4.6. T-Test and Analysis of Variance (ANOVA) Results

The statistical results from *t*-test and ANOVA in evaluating the association between households' knowledge and perception to partake in e-waste management based on demographic and socio-economic factors are presented in Tables 6 and 7. *t*-test results between gender, knowledge and perception are tabulated in Table 6 which indicated that there is a statistically significance between gender and knowledge on e-waste management (*p*-value 0.003) while there was no statistical significant difference between gender and perception (*p*-value 0.318) on e-waste management. Additionally, in Table 7, a one-way ANOVA was performed to examine if the demographic and socioeconomic variables of the respondents could influence their willingness to participate in e-waste management. Accordingly, there was a statistically significant difference associated with households' willingness to participate in e-waste management based on income, years of employment and educational levels. The results further revealed that there was no statistically significant difference associated with e-waste management based on age and marital status.

Table 6. Knowledge and perception *t*-test results on willingness to participate in e-waste management.

	Gender	N	Mean Difference	Standard Deviation	*t*	Significance
Knowledge	Male Female	131 69	2.4721 2.6887	1.8291 1.9384	0.2413	0.003
Perception	Male Female	131 69	2.3361 2.2401	1.1065 1.0289	0.5523	0.318

Note: N = Number of respondents; *t* = computed test statistics, significant at *p* => 0.05.

Table 7. ANOVA results on knowledge and perception to participate in e-waste management according to demographic and social factors.

Variable	Demographic and Socio-Economic Factors	Sum of Squares	df	Mean Difference	F	Sig.
	Age					
Knowledge	Equal variance assumed Equal variance not assumed	73.552 734.882	9 114	1.73621 1.42091	1.430	0.782
Perception	Equal variance assumed Equal variance not assumed	72.890 719754	8 108	1.65438 1.38872	0.893	0.656
	Marital status					
Knowledge	Equal variance assumed Equal variance not assumed	12.544 313.832	8 203	1.6743 1.3281	1.948	1.328
Perception	Equal variance assumed Equal variance not assumed	10.3294 224.612	9 113	1.4832 1.3982	1.254	0.952
	Educational level					
Knowledge	Equal variance assumed Equal variance not assumed	14.812 623.911	5 199	2.56623 2.31058	0.752	0.004
Perception	Equal variance assumed Equal variance not assumed	13.328 384.594	6 145	1.3665 2.4332	0.334	0.003
	Income					
Knowledge	Equal variance assumed Equal variance not assumed	4.238 227.354	8 218	2.19932 2.02643	0.762	0.000
Perception	Equal variance assumed Equal variance not assumed	6.291 201.443	5 216	1.94445 1.53821	0.233	0.000
	Years of employment					
Knowledge	Equal variance assumed Equal variance not assumed	2.632 164.874	4 221	3.04332 2.93338	0.692	0.002
Perception	Equal variance assumed Equal variance not assumed	2.372 113.6643	4 153	1.4384 2.38245	0.492	0.000

Where df means Degree of Freedom; F: F ratio; Sig: Level of Significance at $p < 0.05$.

4.7. Limitations of the Study

This study offers a preliminary synopsis on the appraisal of household knowledge and perception on e-waste management in Limpopo Province, South Africa, but the results cannot be generalized for the entire country as a province out of the nine provinces was used for the study. The results however point toward more sensitive indicators of e-waste management in the country. To draw the inference that can be generalized, a research study of this nature requires a larger sample size of thousand participants. More so, as a descriptive study, a simple random sampling method was employed, thus could not accurately denote the entire community of the e-waste management stream. Relied upon by the study were self-administered semi-structured questions on e-waste knowledge and perception. This may recall bias answers by the participants due to social desirability as some participants may over-report their knowledge and perception to be viewed as good by the data collectors.

5. Conclusions and Policy Implications

The findings from this study demonstrated that knowledge and perception regarding e-waste is the primary influencing factor in activating a proper waste management intention. This indicates that household participation in e-waste management is based on their understanding of how best to manage the waste stream. Thus, educational and awareness campaigns are indisputable across every platform and should be intensively promoted as this could change the perception of households' about e-waste and environmental consciousness. From the survey, although not a leading factor as a reason for changing electronic devices, the impact of new designs/upgrades and social pressure factors could soon trigger an increase in the e-waste stream. Evidently from the literature, there are several toxic constitutes found in different components of e-waste, improper management of these waste streams could release toxins into the atmosphere which are detrimental to human health. E-waste also poses environmental hazards if improperly disposed of in the landfill sites as toxic particulates and heavy metals could leach out and contaminate the soil-water-crop-food pathway by further creating health risks and also affecting the aquatic ecosystem of the organisms. To avert the aforementioned, the government should therefore accelerate the willingness of households to pay for proper waste disposal methods. This will positively protect the environment while also providing a source of income for the province. From the formulated hypothesis on e-waste, the study revealed that there was a statistically significant difference between gender and knowledge and also the willingness of the households to participate in e-waste management based on income, years of employment and educational levels. This can be overcome by creating soft measures such as more gender-sensitive awareness programs on the willingness to participate in e-waste management. Increasing awareness, capacity building and information campaigns are critical in the promotion of proper e-waste management programs at the household level. The cost charged to the households should however be considerately inexpensive in order not to discourage them from participating in the scheme as income earned and years of employment plays a pivotal role in households. As part of corporate social responsibility, manufacturers that produce electronic devices, as well as the vendors, could also play a role in the management of these waste streams through programs such as extended producer responsibility. Although the involvement of this nature will require collaboration with the relevant stakeholders as the logistic arrangements and financial implications could be a mammoth task before such commitment can be achieved. The outcome of this study can also serve as a source of useful information in the planning and improvement of e-waste management in households of other provinces or countries that exhibit similar characteristics.

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