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Sustainable Practices in E-Waste Management: A Study of Electronic Repair Technicians in Ho Municipality, Ghana

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Abstract

Ghana is currently grappling with a formidable electronic waste (e-waste) challenge that poses significant threats to both the ecosystem and human well-being. This study delves into the e-waste management and recycling practices within a crucial sector of the industry, aiming to shed light on the issue and formulate comprehensive strategies for policy implementation and recycling initiatives in the Ho municipality, the regional hub of the Volta region, as well as in Ghana as a whole. Between March and May of 2022, a meticulous sampling process identified 150 electronic service technicians for participation. The data gathered was processed and analyzed using SPSS v16. The analytical techniques employed included one sample T-test, Likert scale assessments, and binary logistic regression. The results unveiled a significant gap in knowledge among repairers regarding government laws and e-waste disposal protocols. Qualifications emerged as a noteworthy factor influencing awareness levels (5.066, 95% CI: 1.098–3.860, $p = 0.024$, <0.05). While respondents generally acknowledged the environmental impact of e-waste, they exhibited limited awareness concerning the hazardous substances contained within it. Notably, two predominant e-waste management strategies surfaced: storage and eventual sale to scrap dealers. Regarding recycling methodologies, a majority (52%) expressed a preference for a nominal fee-based approach. These gaps highlight the need for stakeholders to publicize appropriate methods to recycle e-waste and the associated legal framework across all members of the Ghana Electronic Service Technicians' Association (GESTA) social media platforms in conjunction with local government assemblies to reshape repairers' perceptions of e-waste and increase environmental awareness, aligning with the Sustainable Development Goals (SDGs).

Keywords: Awareness, Toxic substance, Environmental impacts, Human well-being, Ecosystem, Recycling: Ghana electronic service technicians' association.

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1 | Introduction

The management of e-waste has emerged as a pressing global concern. It now represents the fastest-growing segment within the formal municipal waste stream worldwide [1], [2]. Presently, there are various kinds of Electrical and Electronic Equipment (EEE) available worldwide due to swift technological advancement [3]. The rapid advancements of technology have led to shorter product lifecycles, as new and improved electronic devices are released frequently. This results in older devices becoming obsolete more quickly, leading to their disposal [4].

According to the European Commission's definition, e-waste encompasses EEEs that have been discarded. This category encompasses a diverse array of electronic products that have either reached their end of life or are no longer desired or functional [5]. Unlike regular municipal waste, specific components found in electronic products contain hazardous substances that present a significant risk to both the ecosystem and well-being [6]. Typically, EEEs can be categorized into three (3) groups: 1) "white goods," including refrigerators, washing machines, and ovens, 2) "brown goods," including devices such as radios, audio equipment, and televisions, and cameras, and 3) "grey goods," consisting of laptops, mobile phones, recorders, and so on. Due to their toxic composition, grey goods pose greater challenges for recycling compared to white or brown goods [7]. This form of waste poses substantial disposal and recycling challenges, and they entail specific recycling and disposal requirements to mitigate the adverse environmental impact of e-waste [8], [9].

In recent years, there has been a notable upsurge in e-waste imports into Ghana, making it crucial to enhance understanding and implementation of effective e-waste management strategies. This is essential to safeguard public health and prevent potential environmental damage [10], [11]. Annually, Ghana imports a staggering 40,000 tonnes of electronic waste, solidifying its position as a significant hub for recycling on the African continent. As a result of the waste invasion, some residents in the receiving regions have been displaced, raising serious health issues. The communities in various cities in Ghana are grappling with the challenge of managing both technological and radioactive waste due to the lack of sufficient awareness and limited interest from the government in addressing this pressing issue [10], [12]. Annually, the global production of e-waste ranges from twenty (20) to fifty (50) million tonnes, as indicated by the United Nations, and it is likely to grow more, with recycling initiatives not failing to control the global surge [13]–[16].

In order to tackle the previously mentioned problem, governments worldwide have put various regulations and policies into place. While e-waste policies, laws, or regulations apply to 71% of the global population, there is a need for further efforts to implement and enforce them effectively, encouraging the establishment of collection and recycling systems [13]. In Ghana, act 917 and LI 2250 for regulating e-waste were enacted in 2016 [10], [17]. By creating a comprehensive legislative framework for waste management in the country, the act intends to address the issues connected with hazardous and electronic waste, protect the environment, and safeguard public health [18]. The legislation also imposes accountability on EEE producers and importers to take charge of managing their products when damaged.

This approach incentivizes producers to develop recyclable products to foster the development of a circular economy for electronic goods [19]. Despite the introduction of these regulations in Ghana, the country still falls short in implementing sufficient practices for the suitable disposal and recycling of the waste generated. In contrast, Ghana is also a participant in the "Basel Convention," a global initiative aimed at safeguarding the well-being and the ecosystem by regulating the movement and promoting environmentally responsible handling of hazardous wastes worldwide [9]. The Basel Convention, implemented in 1992, represents a significant global agreement concerning the control and disposal of hazardous wastes across borders. The main goal is to regulate the cross-border transportation and disposal of hazardous wastes, excluding radioactive waste, while promoting the reuse and recycling of exported waste [20]. However, the Basel Convention does not oversee the handling of used items or certain types of e-waste scrap, such as component circuit boards [9]. Although Ghana became a party to the Convention in 2005, the integration of its provisions into national legislation is still pending [10].

Additional research indicates that e-waste poses significant challenges for urban practitioners in developing countries, as many of them lack modern environmental management infrastructure [10], [21]. Developed countries, which tend to consume more electronics, generate larger amounts of e-waste. These nations generally have well-established e-waste management systems and specific regulations in place [22]. In these contexts, informal waste collectors, often referred to as scavengers, are primarily responsible for sorting and gathering e-waste from city garbage bins and landfills. Unfortunately, these scavengers and repairers often dispose of the e-waste in environmentally hazardous ways [23].

Effective management, such as dismantling, recovering materials, and ultimate disposal, has significant implications for fostering a sustainable and healthy society [22]. In Ghana's urban slums, the processing of e-waste is predominantly carried out by unqualified workers without protective gear, accounting for more than 95% of the total [10]. Electronic repair technicians and scrap merchants play vital roles in e-waste management. However, Ghana currently lacks clear plans and regulations for e-waste disposal. Consequently, companies responsible for managing e-waste have had to develop disposal methods that may not be environmentally sustainable, socially acceptable, or financially feasible [1], [10]. Unfortunately, e-waste is piling up in certain repair workshops across the country due to outdated or malfunctioning equipment, leading to storage and disposal challenges. Therefore, it is crucial to examine the perspectives of electronic repairers regarding e-waste management and the associated health risks and hazards [1].

Proper management also encompasses various practices, including secondary use, controlled recycling, component recovery, and landfilling [7], [24]. However, the preferred method depends on the existing size in different nations. Presently, a significant portion of e-waste generated in developing nations is handled without regulation by the informal division, which employs harmful techniques such as open burning, unregulated landfill disposal, open dumping, informal dismantling, and artisanal recycling [24], [25]. This exposes the general public to potential health risks associated with e-waste. In order to avoid the high costs associated with proper disposal, many developed nations opt to export their e-waste to developing countries like Ghana and India [9], [24].

Understanding the need for and potential growth of the overall management system requires research on consumer awareness, consumption, disposal, and recycling behaviours related to e-waste, and this area of study has become increasingly popular [3]. The following in *Table 1* is a summary of the findings from these studies, which demonstrate the awareness levels of e-waste across several regions and countries.

Table 1. A comparative summary of related work on e-waste management.

S/No.	Reference	Research Aim	Findings
1	[26]	Investigated the dynamics of e-waste disposal options in Tamale, Ghana.	The survey participants commonly reported two prevailing disposal methods: selling e-waste to scrap merchants and donating it. The choice of these management practices was influenced by factors such as age, level of education, and income of the respondents.
2	[27]	Focused on promoting a well-established e-waste management practice within service technicians' workshops, with the ultimate goal of fostering a sustainable and healthy society in Nigeria.	The study revealed that electrical/electronic technicians in Nigeria employ hazardous approaches to handle e-waste, including disposing of it in flowing water and swamps, as well as using it for landfill purposes.
3	[28]	Evaluated the economic advantages of extracting obsolete electronic materials in the Wa Municipal area, Ghana.	The results verified significant economic opportunities associated with e-waste, including income generation for youth, revenue generation for municipal governments, and the availability of raw materials for various economic applications.

Table 1. Continued.

S/No.	Reference	Research Aim	Findings
4	[29]	Evaluated household awareness as well as readiness to engage in e-waste management in Jos, Plateau State, Nigeria.	The findings showed that illegally disposing of e-waste in public areas alongside other household waste, hoarding e-waste indefinitely, and selling it for potential reuse were the three most common methods.
5	[30]	Evaluated and provided a detailed e-waste management evaluation in Sub-Saharan Africa.	According to a comprehensive study assessment, the biggest barriers to successful e-waste management are a lack of regulation and inadequate recycling facilities.
6	[31]	Investigated the amount of public concern about e-waste, their disposal habits, and the estimated value of possible abandoned mobile phones in Dubai.	The survey's findings showed gaps in home e-waste awareness and disposal practices, and it was found that recycling rates were low.
7	[1]	Investigated e-waste awareness and management practices among electronic repair professionals and scrap merchants in South Delhi, India.	The majority of electronic repair technicians and scrap merchants never knew about e-waste. As knowledge within these categories improved, so did awareness of e-waste, which was statistically significant.
8	[32]	Emphasized the importance of e-waste management approaches for environmental sustainability by conducting empirical investigations in India.	Despite the growing acceptance of "Extended Producer Responsibility" (EPR), e-waste production and processing are not well understood, and only a few people know about e-waste management.
9	[33]	The study looked at how households in South Africa's Limpopo Province understood and felt about managing e-waste.	A significant majority of respondents (76%) expressed concerns about the detrimental effects. Additionally, an overwhelming majority (85%) of poll respondents indicated their Willingness To Pay (WTP) for appropriate e-waste disposal methods.
10	[24]	Examined customers' knowledge, beliefs, and practices about e-waste management in Kampala, Uganda.	According to the findings, two-thirds of electronics customers have little awareness of e-waste management. More customers had favourable attitudes regarding e-waste management.
11	[10]	Examined how commercial consumers perceived and used electronic waste management strategies in Ho, Ghana.	The participants knew a lot about e-waste and how it affected commercial consumers negatively, but they knew very little about legislation and government regulations.
12	[34]	Assessed Addis Ababa's e-waste traders, collectors, disassemblers, repairers, and storers' knowledge and management.	The statistics revealed that a considerable percentage of dismantlers, vendors, and repair and maintenance professionals possessed inadequate knowledge about e-waste management. The prevailing practices among these groups were limited to hazardous disposal, unsafe storage, and transferring e-waste to other users.

The impacts of climate change have necessitated a shift towards sustainable waste management, prompting governments and civil society to prioritize the attainment of Sustainable Development Goals (SDGs). E-waste, a critical facet of these objectives, demands enhanced comprehension and greater awareness to promote health, environmental safeguarding, job creation, and economic advancement. Realizing the vision of 'Waste-Wise Cities' calls for worldwide engagement from all parties in the proper handling, minimizing, reusing, reevaluating, and recycling of waste. The awareness of stakeholders plays a pivotal role in actualizing these aspirations [35]. The key players in the e-waste industry in the Volta region and many other regions of Ghana have not been the focus of studies on e-waste awareness and management. Such information is crucial in determining the workforce's awareness of e-waste management practices and the risks associated with inadequate e-waste management despite its increasing popularity as a result of the expanding low-income workforce in Ghana's demand for it.

As a result, the primary goal of this study is to investigate e-waste-related knowledge and management, as well as associated variables, among electronic service technicians who also play major roles in e-waste-related businesses. This present study bridged the gaps by enriching the current literature on e-waste management among service technicians in Ghana and providing an additional dimension to the understanding of the views of repairers' perceptions of the management of e-waste. This will not only notify the government and stakeholders about the extent of the growing e-waste threat but will also create awareness and plans to embark on advanced awareness campaigns, policy implementation strategies, and an e-waste recycling program that will provide data to direct suitable and sustainable interventions for Ho municipality and Ghana at large.

2|Materials and Methods

2.1|Study Background

The Volta Region has five municipalities, including the Ho municipality, which was established by Act No. 2074 of 2012. Ho, the Volta Region's capital city, has been chosen for this study. *Fig. 1* illustrates the geographical location of Ho, a city situated between latitudes 6° 20' 1" and 60° 55' 1" and longitudes 0° 12' 1" and 0° 53' 1". It covers an entire landmark of 11.65 km^2. The major cities in the region experience temperatures ranging from 22^o to 32^o C. The city has a population of 180,420 residents [10], [36], [37].

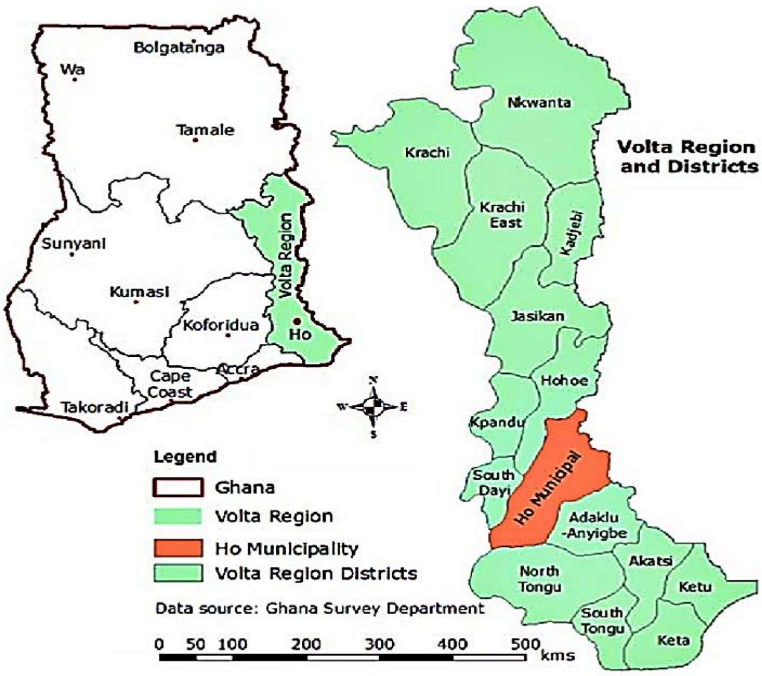

Fig. 1. Map of Ho municipality [37], [38].

2.2|Sample Size Estimation

A focus group of 150 registered service technicians who worked as electronic repairers were selected using a random sampling strategy. To determine the suitable sample size for small populations, researchers employed the formula presented as *Eq. (1)*, which was originally developed by [39]. This calculation was based on certain assumptions for the selected registered service technicians located within the city. The assumptions included a population size (N) of 174, an estimated percentage of success (p) and failure (q) both set at 50%, a margin of error (E) of 3%, and a standard score value (Z) of 1.96 for a 95% confidence level. After computation, the minimum required sample size (n) was determined to be 150.

$$n = \frac{NZ^2pq}{(E^2(N-1) + Z^2pq)}. \quad (1)$$

2.3 | Study Instrument Design

In this study, a questionnaire served as the primary tool for data collection. A series of questions was formulated, taking reference from [10], and respondents were asked to indicate their chosen answers. The questionnaire was structured into five segments, predominantly consisting of closed-ended questions. The initial part requested demographic information. The second part explored participants' general awareness of e-waste, familiarity with government laws and regulations, and awareness of environmental and health perils associated with e-waste. The third segment focused on respondents' attitudes toward e-waste disposal methods and their perceptions of the overall e-waste storage conditions. In the fourth segment, participants were asked to rate their insight into the effect of e-waste on the ecosystem on a "four-point Likert scale". Lastly, the fifth section examined participants' views on the importance and benefits of e-waste management programs and strategies. This section utilized a "five-point Likert scale" to assess perceptions.

2.4 | Data Collection Procedure

This was a cross-sectional study conducted between March and June 2022 on e-waste awareness, perceptions, and disposal behaviours. A randomly selected focus group of 150 electrical and electronic service technicians provided qualitative data. This suitable technique was employed to ensure fair representation and inclusion of workshop heads (Mastercraft) in the study. The master craft electronic repairers, aged 18 and above, who had lived and worked in the city of Ho for at least six months before the study and were members of Ghana Electronic Service Technicians' Association (GESTA), were eligible to participate in the survey. GESTA is an association of skilled technicians with over 2,000 members in all sixteen regions of Ghana.

2.5 | Data Analysis

The questionnaire replies were coded after they were verified for discrepancies and ambiguities. The collected data were processed using SPSS version 16. The analytical methods included Cronbach's alpha to assess the validity of the test items, binary logistic regression to assess the awareness of e-waste and the presence of harmful components, one-sample T-testing to evaluate the benefits and strategies of effective management programs; Likert scale analysis to assess the effects of e-waste on the environment and the storage conditions, and finally, descriptive statistics for analyzing the challenges, method of disposal, and preparedness to pay for final disposal.

3 | Results

The study's main objective was to evaluate how registered electronic repair shops in the Ho municipality of Ghana view and understand e-waste management. The responses provided by the participants to the questionnaire were analyzed and presented as the study's findings.

3.1 | Reliability Test

Cronbach's alpha was employed to evaluate the reliability of internal consistency. When the Cronbach alpha falls below 0.30, it is generally accepted that the data cannot be trusted. When the Cronbach alpha is greater than 0.70, however, the data is considered credible [40], [41]. Cronbach's alpha was estimated in this study using the statistical program SPSS version 19. The Cronbach's alpha for the overall data (0.723) was found to be higher than 0.70. Thus, the results prove the data is reliable and consistent for the test items.

3.2 | Bio-Data of Respondents

Table 2 presents the biodata of the participants, revealing that males constituted 94% of the respondents, while females accounted for 6.0%. These results indicate a male-dominated presence in electronic equipment repairs within the Ho municipality. Additionally, the data indicates that 11% of the respondents fell within the 18 to 25 age range, 16% fell within the 26 to 45 age range, 67% fell within the 46 to 60 age range, and a mere 6.0% were above 60 years old. This finding suggests that the majority of electronic repairers in the municipality were below 60 years old.

The results also demonstrate that 23% of the respondents were Junior High School (JHS) leavers, a majority of 53% of the respondents were Senior High School (SHS) leavers, and 24% of the respondents were tertiary school graduates. This finding suggests that the majority of the repairers in the municipality had at least a middle school education.

With regards to the work experience of the respondents, the results depict that 5% had been service technicians for less than a year, 11% for 2–5 years, and a majority of 65% for 6–10 years. Only 19% had been in service for over 10 years. This result shows that most of the electronic service technicians in Ho municipality had at least 10 years of working experience and, therefore, were equipped with sufficient knowledge to address the research inquiries effectively [23].

Finally, the average monthly income of the respondents was accessed. As depicted in *Table 2*, 8% earned between US$50 and US$100 monthly. A good number of 20% also earned between US$110 and US$150 in a month. The majority of respondents (62%) earned between US$160 and US$200 monthly. Only a few represent the 10% earned above US$200.

Table 2. Biodata of respondents (n = 150).

Demographic Characteristic	Category	Frequency (n)	Percentage (%)
	Male	141	94.0
Gender	Female	9	6.0
	Total	150	100.0
	18 – 25	16	11.0
Age (years)	26 – 45	24	16.0
	46 – 60	101	67.0
	Above 60	9	6.0
	Total	150	100.0
	JHS	34	23.0
Educational level	SHS	80	53.0
	Tertiary	36	24.0
	Total	150	100.0
	Less than 1	7	5.0
	2 – 5	17	11.0
Working experience (years)	6 – 10	97	65.0
	Over 10	28	19.0
	Total	150	100.0
	50 – 100	12	8.0
Average monthly income (US$)	110 – 150	30	20.0
	160 – 200	93	62.0
	Above 200	15	10.0
	Total	150	100.0

*Source: Field Data, 2022

3.3 | Awareness of E-Waste

3.3.1 | Awareness level, laws and government legislation, health and environmental risks

Table 1 presents the results of the binary logistic regression analysis conducted on the collected data. The independent variables used as predictors for the observed outcome for this analysis were the biodata of the respondents, with the exception of 'income'.

Table 3. Awareness of e-waste, government rules, and its harmful impacts.

Test	Step 1	Wald	Sigf.	Exp (B) (OR)	EXP (B) of 95.0% C.I.	
					Lower	Upper
1: Awareness of e-waste	Gender	0.004	0.952	0.935	0.121	9.411
	Age	0.008	0.927	1.032	0.528	2.018
	Qualification	0.240	0.624	0.831	0.396	1.743
	Experience	0.104	0.748	0.893	0.450	1.775
2: Awareness of government laws and legislation	Gender	0.185	0.667	0.689	0.126	3.756
	Age	1.135	0.287	0.737	0.421	1.292
	Qualification	5.066	0.024	2.059	1.098	3.860
	Experience	0.138	0.059	1.701	0.980	2.952
3: Awareness of health risk	Gender	0.184	0.668	0.689	0.126	3.772
	Age	0.989	0.320	0.320	0.400	1.349
	Qualification	0.180	0.671	0.873	0.468	1.631
	Experience	6.595	0.010	2.069	1.188	3.603
4: Awareness of environmental risk	Gender	0.829	0.363	0.519	0.127	2.129
	Age	0.954	0.329	1.267	0.788	2.039
	Qualification	1.023	0.312	1.027	0.771	2.263
	Experience	0.010	0.920	0.974	0.651	1.713
5: Knowledge of toxic substances found in e-waste	Gender	0.591	0.442	2.334	0.269	20.243
	Age	2.692	0.101	1.543	0.919	2.590
	Qualification	00.058	0.810	1.076	0.594	1.948
	Experience	0.982	0.084	1.630	0.936	2.837

Test:	**1**	**2**	**3**	**4**	**5**
Hosmer and Lemeshow test (*p*):	0.534	0.643	0.340	0.422	0.502
Nagelkerke R^2:	Chi^2=0.323, df=4, p<0.05	Chi^2=7.932, df=4, p<0.05	Chi^2=8.688, df=4, p<0.05	Chi^2=3.409, df=4, p<0.05	Chi^2=6.782, df=4, p<0.05
Classification Accuracy:	87.3%	76.7%	80%	69.3%	78%

a. Predictor(s) entered on Step 1: Biodata of respondent

Based on the findings attained from Test 1 utilizing the Hosmer and Lemeshow test model, it can be inferred that the data aligns well with the model (Chi^2 = 6.050; p-value = 0.534 >0.05). Furthermore, none of the chosen variables exhibits significance at a 5% level. As per the Nagelkerke R^2 test model, the selected variables projected 0.4% as the variance in the awareness level. The overall percentage prediction rate of the model for the awareness level stands at 87.3%, indicating a noteworthy level of e-waste awareness.

From the results projected in Test 2 utilizing the same test model, it can be inferred that the data aligns well with the model ($Chi^2 = 7.932$; p-value = 0.643 >0.05). The level of qualification was found to be related to the probability of being aware of government laws and legislation. The Odds Ratio (OR) for the predictor was calculated as 5.066 (95% CI: 1.098-3.860), with a p-value of 0.024 (<0.05), signifying that at a 5% level, qualification is significant. The model projected that 99.1% of participants were ignorant about government e-waste laws and legislation, while 2.9% were aware of such laws and legislation, resulting in a final prediction percentage of 76.7%.

According to Test 3, the model aligns well with the data ($Chi^2 = 6.793$; p-value = 0.340 >0.05). The predictor "Experience" demonstrated an association with the likelihood of being aware of health risks related to e-waste. The OR for the predictor was calculated as 6.595 (95% CI: 1.188-3.603), with a p-value of 0.010 (<0.05), demonstrating that at a 5% level, experience is significant. The model projected that a mere 9.4% of the participants were aware of the health risks associated with e-waste, while the majority (99.2%) were unaware of the existence of health implications, resulting in an 80% final prediction rate.

The results of Test 4 show that the model is a good fit for the data based on the model ($Chi^2 = 7.063$; p-value = 0.422 >0.05). Similarly, none of the chosen variables show significance at the 5% level. According to the Nagelkerke R^2 test model, the selected variables projected 3.2% as the variance in the awareness level. The test model predicts that 2.2% of the participants are aware of the environmental risks, while the majority (99%) are unaware, resulting in a 69.3% final prediction rate.

Finally, the outcomes attained from the Hosmer and Lemeshow tests indicate a good fit of the model to the data ($Chi^2 = 6.331$; p-value = 0.502 >0.05) in Test 5. Moreover, none of the designated variables showed significance at a 5% level. The Nagelkerke R^2 model demonstrated that only 6.7% of the variability in the awareness of deadly substances in e-waste can be attributed to the chosen predictors. The model's final percentage prediction rate was 78%, suggesting a relatively low level of awareness regarding the presence of deadly substances in e-waste.

3.4 | E-waste Storage and Disposal Mechanisms

3.4.1 | General environment and conditions of stored e-waste

Table 4 describes the outcome of the general environment and conditions of e-waste storage of damaged equipment that is beyond repair and the recovery of valued components.

Table 4. E-waste storage condition and recovery of valued components.

S/N	E-Waste Storage Condition	Good (%)	Bad (%)	Mean
1	How do you assess the general environment and conditions of e-waste storage within your workshop?	13.3	86.7	1.87
	Recovery of valuable component	Yes (%)	No (%)	Mean
2	Do you recover any valuable components from waste electronic devices before disposal?	21.3	78.7	1.79

*Source: Fieldwork 2022

Let;

H_0 = general environment and conditions of e-waste storage are good,

H_1= general environment and conditions of e-waste storage are bad,

SPSS code; Good = 1 and Bad = 2

Critical value =1.5; Reject if the response is below the critical value and accept if the response is above.

According to the findings presented in *Table 4*, the average response value is 1.87, exceeding the critical region value. This provides sufficient evidence to support the acceptance of the null hypothesis, indicating that the general environment and conditions of e-waste storage in the workshops of service technicians in Ho municipality are unfavourable or bad.

Again, let;

H_0 = Retrieval of valuable components from e-waste before disposal is high,

H_1= Retrieval of valuable components from e-waste before disposal is low,

SPSS code; Yes coded in as 1 and no coded in as 2

Critical value =1.5; reject if the response is below the critical value and accept if the response is above.

Based on the information presented in *Table 4*, the average response value is 1.79, surpassing the critical value. Consequently, there is adequate proof to support the acceptance of the null hypothesis and reach the conclusion that the recovery of valued components from e-waste before disposal by service technicians in Ho municipality is limited.

3.4.2 | E-waste disposal challenges

The results of the difficulties encountered by repair shops in getting rid of the generated e-waste are depicted in *Fig. 2*. Among the respondents, a total of 69% attributed their challenge to the lack of collection centres in the municipality. Additionally, 20% of respondents identified inventory purposes as a contributing factor, while 11% cited product complexity as a challenge.

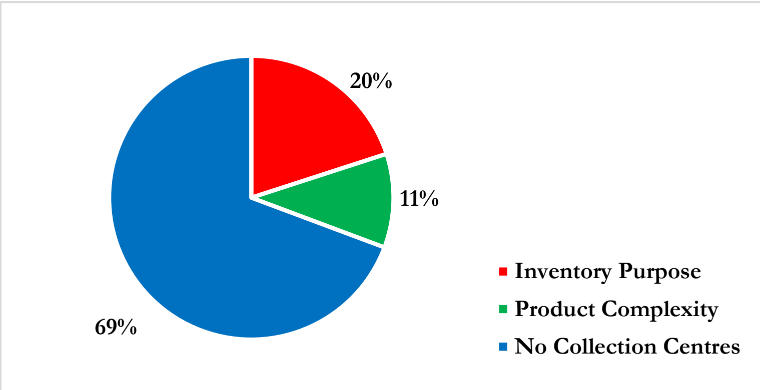

Fig. 2. E-waste disposal challenges.

3.4.3 | Method of disposing of e-waste

Fig. 3 displays the e-waste disposal techniques adopted by the participants. Nearly half of the respondents (40%) reported selling their e-waste, while 25% stated that they stored it. A small majority of 17% admitted to dumping their e-waste, and 13% mentioned burning it. Only a minority of 5% indicated that they donated their e-waste. The findings reveal a prevalent inclination toward negative attitudes regarding e-waste disposal, with a significant number of respondents perceiving selling as the most favourable option.

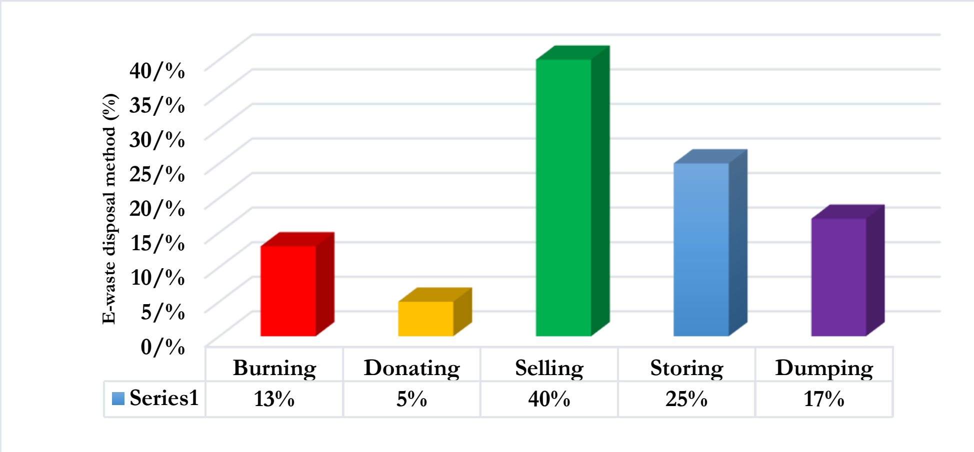

Fig. 3. Methods of disposing of e-waste products.

3.5 | The Effect of E-Waste on Selected Parts of the Ecosystem

The distribution of perceptions regarding the influence of toxic waste on five specific components, namely land, surface water, air, vegetation, and underground water, are presented. Participants' views on the environmental impact of e-waste were rated on a 4-point Likert scale.

The following scores were obtained: No effect (43), Averagely (57), Strong (12), and Very Strong (38).

From the scores obtained, let;

H_0 = the effect on the selected ecosystem is low,

H_1= the effect on the selected ecosystem is high,

SPSS code; very strong coded as 4; strong coded as 3; averagely coded as 2 and no effect coded as 1.

Critical value =2.5; reject if the response is below the critical value and accept if the response is above.

$$\text{Mean Response (M.R)} = \frac{(4\times38)+(3\times12)+(2\times57)+(1\times43)}{150} = 2.30$$

As the calculated mean response is below the critical value, it suggests that the hypothesis can be rejected. This leads to the inference that, on average, the effect of e-waste, as rated by the respondents, does affect the environment.

3.6 | Benefits of E-Waste Management

3.6.1 | Importance and benefits of e-waste management program and strategies

Table 5 presents the results of the one-sample T-testing in verifying the hypothesis. The average result for Test 1's frequent education and knowledge of e-waste management (4.55 ± 0.74) was very near the test's extremely high score of 5. Again, in Test 2, management and recycling of e-waste will help generate income for the country, and individuals' mean score (4.66 ± 0.60) was equally close to the extremely positive score of 5.

Table 5. One-sample statistics.

Test	N	Mean	Std. Deviation	Std. Error Mean		
1: Frequent education and raising awareness will help enlighten individuals on the importance of managing e-waste.	150	4.55	0.738	0.060		
2: The management and recycling of e-waste will help generate income for the country and individuals.	150	4.66	0.600	0.049		
Test	**Test Value = 5**					
	t	**df**	**Sig. (2-tailed)**	**Mean Diff.**	**95% C.I of the Difference**	
					Lower	**Upper**
1: Frequent education and awareness raising will help enlighten individuals on the importance of managing e-waste.	-7.522	149	0.000	-0.453	-0.57	-0.33
2: The management of e-waste will help generate income for the country and individuals.	-6.939	149	0.000	-0.340	-0.44	-0.24

Again, in *Table 5*, the Test 1 score was statistically significantly lower by a mean of 0.45 (95% CI, 0.33 - 0.57) than the normal test score of 5.0, [t (149) = -7.522, p = 0.000]. For Test 2, the result was statistically significantly lower by a mean of 0.34 (95% CI, 0.24 - 0.44) from the expected test result of 5.0, [t (149) = -6.939, p = 0.000]. The estimated values are significant at the 0.05 level. Based on this, the study concluded that there is a significant level of consciousness among service technicians in Ho municipality regarding the benefits and necessity of e-waste management programs and initiatives, leading to the rejection of the null hypothesis.

3.6.2 | Willingness to pay for the final disposal of e-waste

Fig. 4 displays the analysis of the end users' preferred e-waste recycling patterns, including their preparedness to pay a token for the disposal of their e-waste. According to the survey's findings, 52% of participants indicated they would be prepared to pay an e-waste recycling fee if the government creates a viable infrastructure for managing e-waste in the municipality. In other words, 48% remained unwilling to cover the costs.

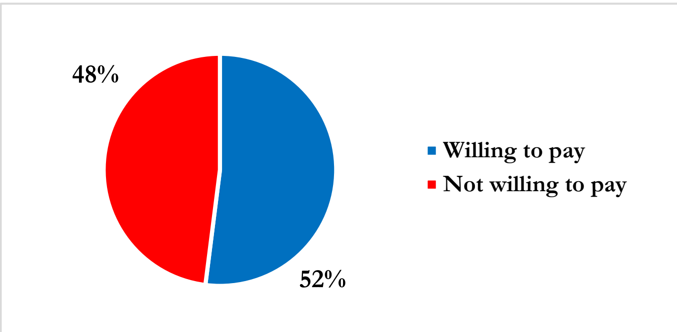

Fig. 4. WTP for the final disposal of e-waste.

4 | Discussions

4.1 | Summary of the Findings

This study assessed e-waste management practices among electronic service technicians in Ho municipality, as these service technicians hold crucial roles in e-waste-related businesses. It is the first of its kind, as previous research mainly focused on e-waste management in different commercial sectors like government institutions, schools, and hospitals in the municipality.

The study revealed that a significant proportion of participants (87%) possessed knowledge regarding the presence of electronic waste. This is in agreement with [10], [22], [29], where respondents under study were aware of e-waste. About 99% of the participants were not aware of the country's e-waste regulations. Similar results were observed in previous studies [10], [24], indicating that a significant portion of individuals lacked awareness regarding existing e-waste regulations. As stated, in 2016, Ghana introduced Act (917) and LI 2250, and these measures were implemented to address the problem of improper e-waste disposal by enforcing stricter regulations on imported goods and increasing the level of accountability. The goal was to improve e-waste management practices and ensure responsible handling of electronic waste in Ghana. E-waste is being handled informally and illegally. Many people in developing nations remain uninformed about e-waste, as well as the pertinent policies, rules, and regulations governing its management, primarily due to inadequate enforcement of existing legislation [42]. Challenges arise in the effective management of e-waste due to the lack of coordination between various agencies and the public in comprehending e-waste regulation. Enhancing awareness of e-waste regulations can play a crucial role in promoting responsible practices for e-waste management and mitigating the adverse consequences associated with improper handling. To address this issue, government authorities and civil society organizations should prioritize raising consumer awareness regarding management and the existing legislation, enabling proper management practices.

In spite of the global recognition of the detrimental effects of e-waste, the participants displayed a notable lack of awareness regarding the adverse health effects associated with e-waste. What is more worrisome is the fact that some of these educated workers were well experienced in the trade area for over ten (10) years, but they do not consider it a serious problem. Similar findings were reported in previous studies [34], [43], indicating that a majority of the surveyed groups were uninformed about the environmental hazards and health risks associated with e-waste. The current low level of awareness among these key workers indicates that e-waste will remain in key public places, posing environmental and health risks in the municipality. This could be attributed to the perceived characteristics of their work methods and the limited workspace they operate in, which differs significantly from the hazardous and often unhygienic environment of dismantlers. However, it should be noted that some repairers handle items like printers and photocopier toners, which are deemed environmentally hazardous and pose health risks. This observation further highlights that most repairers primarily engage in their profession for economic gain. Because of the complexity of their working conditions, repairers are frequently excluded from interventional research; however, they are also more likely to engage in risky health behaviours due to limited monitoring [44]. Sensitization campaigns should thus target those in the electronic repair industry to prevent environmental pollution and health implications during and after repairs.

The respondents in the study have expressed that, on average, e-waste has a negative impact on the environment. However, they lack awareness regarding the existence of dangerous elements in e-waste. They are unfamiliar with the range of perilous materials and their effects on well-being and the ecosystem. Misinformation regarding the dangers of e-waste is prevalent, as noted in previous research. It is imperative to note that e-waste contains toxic substances, and improper recycling and disposal can pose risks to human health and the environment. E-waste consists of many different substances, including toxic materials and heavy metals, as well as organic pollutants [45]. The improper disposal of items in dumping sites as one of the methods for disposing of e-waste, as indicated by respondents, may release these substances into the environment [46], [47]. These e-waste chemicals, as shown in *Fig. 5*, will have long-term environmental consequences that can contaminate the soil, water, and air [7].

Exposure to hazardous chemicals from e-waste can cause health issues such as respiratory and skin disorders. Exposure to Polychlorinated Biphenyls (PCBs), lead, cadmium, and others, as shown in *Fig. 5*, can cause cancer, endocrine disruption, reproductive and developmental problems, and other health issues [48]. Again, the improper storage of e-waste components outdoors, as depicted in *Fig. 6*, leads to them being consistently exposed to moisture and rainwater. This situation presents a potential threat to the local aquatic ecosystem due to runoff from these storage sites flowing into nearby waterways [10]. Lack of awareness among electronic product users about management practices for obsolete equipment contributes to the hazards associated with e-waste. It is crucial, particularly in terms of environmental and health concerns, to ensure that consumers have a comprehensive understanding of sustainable e-waste management practices. By raising public awareness about the dangers of e-waste and emphasizing the significance of safe disposal, the exposure to harmful chemicals generated from e-waste can be minimized. The study by [45] highlights the importance of this aspect.

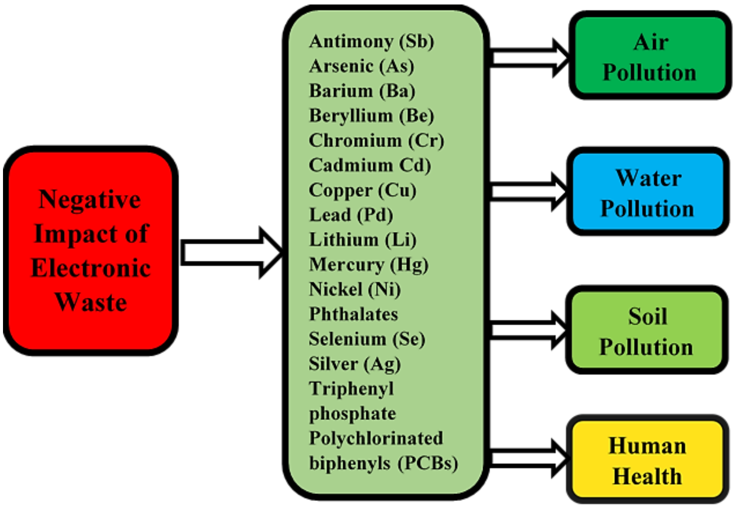

Fig. 5. Chemical contaminants generated from e-waste.

The majority (86.7%) appraised the conditions of e-waste storage within the workshops in the municipality as bad. *Fig. 6* displays some storage conditions for e-waste in some selected workshops in the municipality. However, it was also observed by the researchers that about 90% of the repair workshops do not have proper storage facilities. Most of the obsolete appliances were stored outside the workshops, as displayed in *Fig. 6*. To protect obsolete electronic devices from precipitation, they must be stored on an impervious surface and within a structure or transportation unit.

At all times, outdoor storage is prohibited. Electronic devices should be moved, stored, and handled in a way that keeps them from breaking. Electronic device accumulation must be limited to one year from the date it becomes a waste [49].

Fig. 6. The conditions of e-waste storage within workshops.

The majority of the participants in the study lack knowledge regarding the proper disposal measures for e-waste. The absence of a comprehensive e-waste management system leads to a situation where many repairers resort to selling the e-waste to informal traders, storing it, or even dumping it as an alternative solution. This finding is supported by previous research studies such as those conducted by [24], [34], [50], which have shown that a substantial percentage of e-waste is either sold to scrap dealers and informal recyclers, stored or dumped together with other solid waste. This practice of selling and dumping e-waste with regular solid waste helps prevent unnecessary accumulation, reduces health risks, and minimizes the creation of breeding grounds for rodents, as highlighted by [51]. Inadequate municipal waste management systems frequently encompass indecorous handling of the e-waste flow [52]. In the absence of an official management system for the repairers in the municipality, the most practical method of disposal involves getting rid of e-waste by either selling it off. The average monthly income was also raised as the primary reason for most respondents to sell their e-waste. According to the results in *Table 2*, the majority of respondents earn an average monthly income of US$50 to US$200 per month, and that is insufficient to feed themselves and their families, so selling to informal recyclers who also offer attractive prices allows them to make some cash. The participants further attributed the following challenges to the choice of e-waste disposal methods adopted: The unavailability of collection centres and inventory purpose were rated as the key challenges, whereas product complexity was rated as the last challenge. As depicted in *Fig. 6*, there is a growing tendency among workshops in the municipality to keep old or damaged appliances due to insufficient storage facilities and a lack of appropriate collection centres. Again, the majority of repairers keep an inventory of all broken appliances in their workshops for an extended time because the owners of these appliances often abandon them due to a lack of available parts or the high cost of part replacement. The majority of owners, according to the repairers, show up later for collection, which makes it difficult to dispose of waste appliances as they would prefer, hence, storing them. Raising public awareness of the risks associated with WEEE and the importance of proper disposal methods, as well as the establishment of collection and recycling facilities, can help ensure that old electronics are properly disposed of in the municipality.

The SDG goals, including Goal 3 (Good health and Well-being), Goal 6 (Clean water and Sanitation), Goal 11 (Sustainable Cities and Communities), and Goal 12 (Responsible Consumption and Production), necessitate comprehensive understanding and effective management of e-waste. The connection between E-waste awareness and the attainment of SDGs is intimate. Inadequate treatment resulting from improper disposal can lead to severe health problems [35].

In Ho municipality, service technicians recover a few valuable components from e-waste before disposal. Workshops often handle EEEs informally, utilizing basic technologies like manual disassembly without proper tools and equipment. Through a series of refining and conditioning steps, the workshops employ rigorous techniques to extract the most valuable components from the appliances. These components are then processed to transform them into reusable parts, as illustrated in *Fig. 7* [10]. In workshops, this waste is recycled by using functional parts from one item to repair a similar item. As per the service technicians' statements, the remaining pieces are either discarded outright or stored for incineration [9]. The choice of interest was attributed to the complicated nature of some appliances. Many forms of e-waste are complex products that make it difficult to separate and sort materials efficiently. The technicians need to separate the various materials that make up electronic waste into their constituent parts using rigorous means. Because of the increasing complexity of electronics, each step is labour and time-intensive. Manual dismantling is one process that can't be automated [53]. As with manual dismantling in general, e-waste in repair workshops often contains hazardous materials of various types of toxic elements and has the potential to have an irreversible impact on the ecosystem and human well-being if not handled properly [47]. To minimize the risks related to the manual dismantling of e-waste in repair workshops, it is crucial to adhere to proper safety protocols and utilize proper Personal Protective Equipment (PPE). Repairers should be trained in the safe handling and disposal of e-waste. They should use specialized tools and equipment to minimize the risk of injury or exposure to hazardous materials. It is also recommended to use automated or mechanical processes for e-waste dismantling wherever possible, as these methods can reduce the risks associated with manual dismantling.

Fig. 7. Valuable components from obsolete equipment for reuse.

E-waste serves a dual role: it not only contains toxic substances that have detrimental effects on the ecosystem and human well-being but also holds valuable materials that the recycling industry in numerous countries aims to recover due to their significant economic worth [31]. Following the findings of [54], e-waste contains valuable materials such as precious metals such as gold, copper, silver, neodymium, yttrium, etc. These materials are considered valuable for industry and recycling companies, as highlighted in the study by [52]. Recycling these materials can contribute to the reduction of natural resource depletion. For instance, one million cell phones have the potential to conserve high amounts of gold, copper, silver, and palladium [31].

In the city, despite the practice of open burning to extract valuable and easily separable components from e-waste, the waste heaps remain susceptible to contamination from direct rainfall, which can then contaminate nearby water bodies. This is illustrated in *Fig. 8*. According to the results of samples taken from water and sediment in Ghana, contaminants related to e-waste have made their way into the country's waterways [55]. Water bodies are significantly polluted by e-waste toxins, even though other sources are contributing factors. Also, putting together and burning e-waste inappropriately creates a lot of pollution in the air, which can lead to secondary exposure because pollution can travel long distances from recycling sites to other populated regions [31]. Increased e-waste recycling can be achieved, in part, by increasing the repairers' understanding of the problem and its solutions, and this can be accomplished, among other things, through the promotion of environmental education among the service technicians conducted by their mother association in collaboration with the government ministry responsible for environmental affairs and experts from the industry. This is crucial for advancing SDG Goal 6 (Clean Water and Sanitation) by discouraging practices like burning e-waste and open burning. This will contribute to achieving the SDGs effectively.

Fig. 8. Burning of obsolete devices.

The majority of respondents agreed that it is imperative to establish management strategies and programs to spread the word about best practices in this area. Respondents generally agreed that widespread education about the importance of e-waste management is necessary to raise public awareness and that proper e-waste management and recycling can be a source of revenue for both governments and private citizens. This finding is consistent with [29], which found that the vast majority of respondents were open to taking part in an e-waste management program. Frequent capacity-building workshop programs for the e-waste sector will encourage efficient e-waste management by equipping participants with skills in environmental, health, and safety. The initial and vital measure in managing the e-waste sector and its associated hazards through municipal planning involves implementing collaborative policy measures that aim to improve the sector, maximize its advantages, and safeguard its developmental achievements. [56].

An analysis of the end users' preferred e-waste recycling patterns, including their readiness to pay a token for the disposal and recycling of their e-waste, was conducted. According to the survey's findings, 52% of participants indicated they would be prepared to pay an e-waste recycling fee if the government creates a viable infrastructure for managing e-waste in the municipality. In other words, 48% of respondents were still unwilling to pay for the recycling of their electronic waste. The findings presented in [33], [45], [57] provide support for this viewpoint. Depending on the level of commitment displayed by consumers and their WTP, the municipality and Ghana may be able to generate revenue by charging consumers for the disposal and recycling of electronic waste. In numerous developing nations like Nigeria and Ghana, the absence of e-waste collection facilities results in the majority of electronic waste being either sold, stored, or discarded alongside other types of waste [27]. The effectiveness of recycling could be improved if the municipality were to provide drop-off facilities that could also serve as collection points for the e-waste generated [33]. The transition of consumer practices from conventional to sustainable recycling can only occur when individuals possess comprehensive knowledge about e-waste, including relevant laws, policies, recycling systems, and the associated risks it poses. These ongoing efforts may eventually persuade people to pay the recycling fee [45].

Furthermore, environmental education and awareness are critical methods that will undoubtedly expand the environmental performance of the e-waste business [58]. SDG 12, part of the SDGs, focuses on Responsible Consumption and Production. It aims to establish sustainable patterns in how we use and create goods. Within this goal, Target 12.4 concentrated on e-waste, setting a goal for 2020: to ensure that chemicals and all types of waste are managed in an environmentally sound way, reducing their release into the environment and thus protecting human health and nature. Meeting this target, which has already elapsed, demands a collective effort from governments, businesses, and individuals to create effective e-waste management systems, promote recycling, and spread awareness about responsible consumption and production habits. Through these actions, we can actively contribute to a more sustainable and eco-friendly future.

Finally, the Ho municipality has no e-waste recycling companies. The majority of e-waste collection and recycling work is done in the municipality's informal sector, as reported by [10]. Scavengers or scrap dealers obtain e-waste from repairers through a variety of methods, such as collecting discarded or obsolete devices from repair shops or purchasing discarded devices or components from repairers. The informal industry of dismantling and recycling e-waste for material recovery is rapidly growing in Ho, being seen as a "profitable enterprise." The primary tasks at these scrap dealers' various e-waste dismantling sites, as shown in *Fig. 9(a)*, include gathering e-waste from households, businesses, and public spaces, such as landfills and dumps, sorting by type and quality, to identify components that can be resold or reused, the manual dismantling of this obsolete equipment using primitive tools and methods such as burning and melting to separate metals, particularly gold and copper as shown in *Fig. 9(b).* Refurbishers from Ghana's capital city travel to certain locations to acquire these parts for the benefit of other businesses in collaboration with recycling companies from the nation's capital. While the informal e-waste sector provides a source of income for many of its workers in the municipality, it also poses serious health and environmental risks. According to [9] and [10], individuals are faced with a dilemma of selecting between "poverty and poison." This implies that they are compelled to choose between working in recycling facilities despite the associated health risks or foregoing a salary entirely. There is a critical need to bridge the gap between waste management policies or strategies and their practical implementation on the ground [58]. To address these issues, it is essential to regulate and formalize the e-waste recycling industry, provide training and education for workers, and implement safe and environmentally sound processing methods. This will help to protect workers' health, reduce environmental pollution, and ensure the sustainable management of e-waste. The attainment of Goal 11, which focuses on Sustainable Cities and Communities, hinges on establishing effective disposal mechanisms. Additionally, realizing Goal 3 (Good Health and Well-being) and Goal 8 (Decent Work and Economic Growth) necessitates the adoption of scientifically sound e-waste management practices complemented by a formal recycling framework. This approach not only promotes economic benefits but also contributes to the overall well-being of communities [35].

Fig. 9. a. some e-waste scrap yards, b. recovery of components and metals.

Fig. 10 depicts the existing trajectory of e-waste during and after repairs, as well as its disposal process when it becomes obsolete within the workshops located in the municipality, as discussed. Several sources of e-waste flow to electronic repairers in the municipality. These sources of e-waste include a wide range of electronic devices, from consumer and office electronics such as smartphones, laptops, tablets, televisions, washing machines, microwave ovens, printers, copiers, scanners, computers, and fax machines to industrial electronics such as manufacturing equipment, medical devices, and communication systems, and also electronic components from modern cars such as infotainment systems, sensors, and engine control modules are mostly brought to repair shops for repair when these equipment fail or become outdated.

Fig. 10. The e-waste life cycle from service workshops.

The current body of literature does not provide sufficient details about the quantity of electronic waste and its associated material movement. This lack of information creates obstacles in establishing accurate records, operational regulations, and technical guidance for efficient management of e-waste. Without these measures, it becomes challenging to establish minimum standards for e-waste practices and facilitate their shift from unregulated and informal methods to a more modernized approach and sustainable system that meets the country's needs [10], [59]. The issue of e-waste is a matter of worry due to its significant contribution to the overall volume of solid waste. Because of this, the problem of e-waste is quite complicated and multifaceted [60] and has good, bad, and ugly effects [60]. The positive aspect revolves around the generation of job prospects and the utilization of e-waste as a valuable resource. On the downside, there is the exacerbation of already dire environmental circumstances in developing nations. Lastly, the negative consequence involves the harmful impact on the well-being of workers involved in processing e-waste, given the presence of various toxic elements.

Consequently, effective e-waste management necessitates policy strategies founded on principles of sustainability and bolstered by scientific advancements, technological innovations, and creativity. Enhanced e-waste management can contribute to attaining advantages in social, economic, and environmental realms [61]. By engaging stakeholders and providing education to professionals, the government of Ghana can significantly enhance awareness about the detrimental impacts of inadequate e-waste management practices. Implementing effective e-waste policies will be crucial in promoting improved practices both within the city and throughout the entire country. These efforts are essential in the ongoing battle to adopt environmentally and ethically responsible approaches to e-waste management, ultimately contributing significantly to the achievement of SDGs related to environmental sustainability, economic growth, and responsible consumption and production.

5 | Conclusion

The goal of this study was to find out how current electronic service technicians in Ho municipality manage their electronic waste. The findings of the study indicate that e-waste is growing in the municipality due to the increasing use of electronic devices that easily become outmoded within a short time. There were wide gaps in understanding, perspective, and reported behaviour. Qualification was strongly correlated with the level of participants' knowledge of law and government regulations. Inadequate education, absence of specific regulations and approved disposal methods, and insufficient coordination in handling e-waste have contributed to the development of inadequate disposal strategies.

Hence, the study's conclusion emphasizes that this research offers significant insights to the Ghanaian government, experts, and stakeholders. These findings can be utilized to foster environmental awareness and encourage sustainable e-waste management practices among consumers in Ghana. In light of this, the researchers recommend that education and awareness campaigns should be promoted across all social media platforms of GESTA by stakeholders in collaboration with local government to publish appropriate procedures to recycle e-waste and related legislative frameworks to increase knowledge to change perceptions of e-waste and environmental consciousness among these repairers. By providing education to professionals regarding the consequences of inadequate e-waste management practices and by implementing and integrating effective existing e-waste policies such as the Basel Convention, along with new policies developed in collaboration with foreign partners like the European Union (EU), significant improvements can be made in these practices within the city and the country as a whole.

Furthermore, independent recycling companies and organizations without governmental affiliations in Ghana's capital city are actively engaged in e-waste recycling endeavours. However, additional initiatives are necessary to enhance collection and recycling rates throughout the entire country. This is crucial because e-waste is projected to increase significantly in Ghana, particularly with anticipated higher rates of technology adoption and population growth in the future. In addition, the creation of affordable e-waste collection centres in every municipality of Ghana will encourage sustainable practices and formalize recycling activities.

These initiatives will promote environmentally and ethically responsible approaches within the e-waste industry throughout the country and ultimately contribute to sustainable development in the long term, aligning with the achievement of SDGs.

This research is limited to the Ho municipality, and the survey sample size is relatively small compared to the entire population. Nevertheless, the survey findings are considered a valuable starting point due to the limited exploration of e-waste information in the region and Ghana. Future studies could expand their investigations to encompass other regional capitals and municipalities. Additionally, conducting long-term surveys on larger samples and extending the analysis to different categories of EEEs would be beneficial. These efforts would help identify further gaps within Ghana's e-waste management system and contribute to developing a comprehensive e-waste inventory for improved sustainable e-waste management in the country.

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Conflicts of Interest

All co-authors have seen and agreed with the contents of the manuscript, and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon a reasonable request.

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