

Public Awareness and Recycling Practices of Electronic Waste (E-waste): A Case Study of Perlis, Malaysia

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ABSTRACT

Electronic waste (e-waste) has become one of the fastest-growing waste streams worldwide due to the rapid advancement of electrical and electronic technologies. In Malaysia, the increasing generation of e-waste poses significant environmental and public health challenges, highlighting the need for effective recycling practices. This study assessed public awareness and recycling practices related to e-waste among residents in Perlis, Malaysia. A quantitative survey was conducted using a structured questionnaire administered to 240 respondents selected through purposive sampling from schools, universities, workplaces, and public locations. The findings indicate that although most respondents were aware of e-waste and recognized the importance of recycling, actual participation in e-waste recycling remained relatively low. Limited knowledge of authorized recycling centers, accessibility issues, and insufficient practical guidance were identified as the main barriers to participation in recycling. Respondents also recommended strengthening public awareness campaigns and expanding e-waste collection facilities to improve recycling practices. The study concludes that increasing awareness alone is insufficient to promote sustainable e-waste management. A comprehensive approach that integrates continuous environmental education, accessible recycling infrastructure, and supportive government policies is essential to encourage responsible recycling behavior. The findings provide practical guidance for policymakers and stakeholders in developing more effective e-waste management strategies and contribute to the achievement of Sustainable Development Goals (SDGs) 3 (Good Health and Well-being), 6 (Clean Water and Sanitation), and 11 (Sustainable Cities and Communities).

Keywords: Electronic waste, Environmental contamination, Hazardous materials, Sustainable recycling, Community awareness.

1. INTRODUCTION

Electrical and electronic waste, better known as e-waste, is equipment that is no longer used and no longer provides any value. In Malaysia, e-waste is listed as a scheduled waste under the Environmental Quality (Scheduled Waste) Regulations 2005 [1]. It is defined as waste from electrical and electronic installations that contain components such as accumulators, mercury switches, glass from cathode ray tubes, and other activated glass or polychlorinated biphenyl capacitors, or that are contaminated with cadmium, mercury, lead, nickel, chromium, copper, lithium, silver, manganese, or polychlorinated biphenyls. E-waste is generally divided into two main types, according to its source of generation, namely e-waste generated from the industrial sector and household e-waste. It is categorized as scheduled waste in the First Schedule under Code SW110 [1].

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The Global E-Waste Monitor 2024 helps to reveal that the world has produced approximately 62 million tons of e-waste each year, although only a quarter was collected and recycled, which shows that the difference between increased consumption and successful recovery continued to exist [2]. This global challenge is equally evident in Malaysia, where domestic e-waste output grew from 22.7 million units in 2023 to 24.5 million units in 2025. Despite the establishment of 17 full-recovery and 106 partial-recovery facilities nationwide, formal processing rates remain low at just around 21%. The fact that in 2024, more than 200 unlicensed e-waste recycling plans were found only makes it even harder to enforce, as the uncontrolled disposal procedures are continuing to threaten the ecosystem and the population.

In Malaysia, e-waste is categorized as scheduled waste because it has characteristics such as flammability, corrosiveness, reactivity and toxicity. Since e-waste poses a risk to human health and is a threat to the environment, it should be collected and sent to a recovery facility, more commonly known as a collection center or recycling center. Here, the e-waste recycling process will take place. The e-waste sent will undergo several important processes before becoming valuable metals that will be reused to produce new electrical and electronic products. Malaysia will strengthen the management of e-waste through the Extended Producer Responsibility (EPR) framework, which involves producers, importers, consumers, and registered collection centers under the Department of Environment. In Malaysia, 200 registered e-waste collection centers have been introduced nationwide to make it easier for the public to send and dispose of e-waste in an environmentally sound or environmentally friendly manner.

The level of awareness of Malaysian society towards e-waste recycling is still low compared to efforts to recycle other materials, such as plastic or paper. The importance of education in raising awareness about e-waste recycling, through social media campaigns and seminars organized by local authorities and non-governmental organizations (NGOs), can increase awareness. Noor et al. [3] have shown in their study that awareness among young people, especially university students, has increased due to greater exposure to the dangers of e-waste and the benefits of recycling through environmental education programs. Wider exposure to e-waste recycling in schools and universities is also seen to be effective in changing students' attitudes towards electronic waste management.

This case study aims to analyze the level of public awareness in the state of Perlis regarding e-waste recycling, the factors that influence their attitudes towards managing used and damaged domestic goods, and the performance of government and private-sector support involved. More e-waste should be disposed of, and it needs to be managed properly. This initiative to collect and recycle e-waste supports the goals of SDG 3: Good Health and Well-being, SDG 6: Clean Water and Sanitation, and SDG 11: Sustainable Cities and Communities for the Sustainable Development Goals (SDGs), and towards the implementation of the Circular Economy, and also through the promotion of informed recycling practices and the strengthening of sustainable waste management frameworks.

2. MATERIAL AND METHODS

This case study employed a quantitative research approach to investigate the level of awareness and practices of e-waste recycling among residents of Perlis, Malaysia. Data were collected using a structured questionnaire comprising 11 questions. The questionnaire consisted of two sections. The first section collected respondents' demographic information, while the second section examined respondents' knowledge of e-waste, awareness of e-waste recycling, recycling practices, recycling methods, barriers to recycling, frequency of recycling, self-awareness, and recommendations for improving public awareness and recycling practices.

The questionnaire was developed based on previously published studies on e-waste awareness and recycling behavior and adapted to suit the objectives of this research. A pilot study was conducted among office staff prior to the actual survey to assess the clarity, readability, and comprehensibility of the questionnaire. Based on the feedback received, minor revisions were made to improve the wording and presentation of several questions before the final questionnaire was distributed.

A purposive sampling technique was employed to recruit respondents who met the study's inclusion criteria. Respondents were selected from schools, universities, government and private offices, and public places, including mosques, stadiums, morning markets, and community events, to ensure participation from diverse age groups and occupational backgrounds. A total of 240 respondents, aged between 13 and 65 years, participated in the survey, including school and university students, government and private sector employees, self-employed individuals, unemployed individuals, retirees, and housewives.

The questionnaire was administered online using Google Forms, and participation was voluntary. The collected data were analyzed in Microsoft Excel, using descriptive statistics (frequencies and percentages) to summarize the respondents' awareness, perceptions, and e-waste recycling practices.

3. RESULTS AND DISCUSSION

3.1 Demographic Profile of Respondents by Age Distribution

Figure 1 illustrates the age distribution of respondents involved in e-waste awareness and recycling practices. The largest proportion of respondents falls within the 19–30 years age group (90 respondents), indicating that young adults constitute the dominant demographic in this survey. The questionnaire for this study is indeed focused on secondary schools and universities. This is because awareness regarding e-waste needs to be implemented from an early stage. The younger generation, also known as Gen Z, has been exposed to gadgets since childhood. Therefore, it is appropriate that awareness should be given earlier, as a guide to the next generation. Their strong representation suggests that e-waste awareness initiatives may have greater reach and impact when targeted at younger populations.

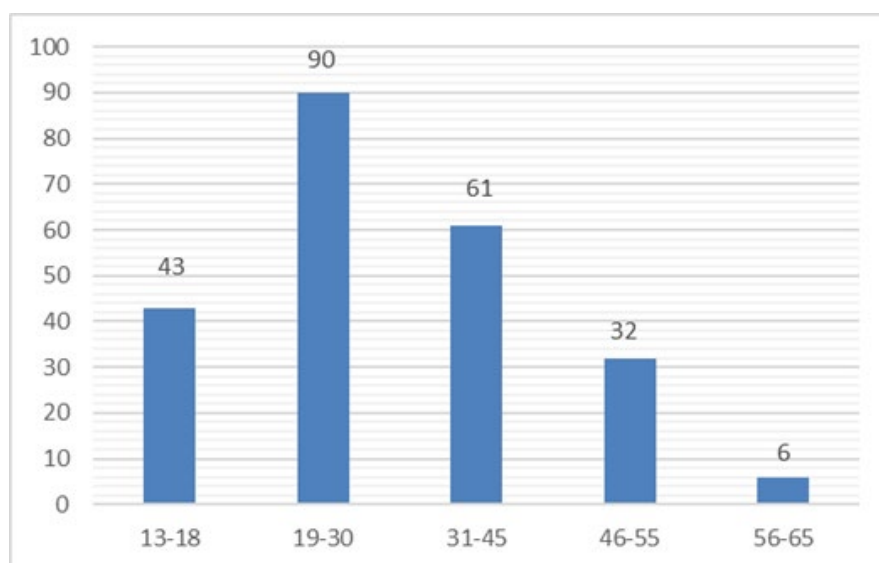


Figure 1: Respondent by age (years old).

The 31–45 years age group accounts for 61 of the respondents, representing a significant segment of the working-age population. Individuals in this category are likely to be regular consumers of electronic products and household use, making them an important group in terms of e-waste generation and recycling behavior. Apart from that, awareness and e-waste recycling practices for their group also need to be taken into account. Their participation reflects the relevance of e-waste management issues across economically active age groups. This may determine whether the knowledge and awareness they have gained can influence their families and the younger generation.

Respondents aged 13–18 years constitute 43 of the moderate involvement from adolescents. This group is particularly important for long-term sustainability, as early exposure to e-waste awareness can foster responsible recycling habits in the future. The knowledge and awareness in this group may not be as high or as widespread. This group of secondary school students is still at a stage that requires more exposure. The presence of this age group highlights the potential role of educational institutions in promoting awareness of e-waste recycling.

In contrast, the 46–55 years (32 respondents) and 56–65 years (6 respondents) age groups are underrepresented. These groups seem to have limited exposure to digital surveys or to perceive e-waste issues as less relevant among older adults. It also suggests a potential gap in awareness or engagement that should be addressed through targeted outreach and community-based programs. Overall, the age distribution indicates that e-waste awareness and recycling efforts are currently more prominent among younger and middle-aged populations. Understanding these demographic differences is crucial for designing effective policies and awareness campaigns aimed at improving e-waste recycling practices across all age groups.

3.2 Level of Knowledge About E-Waste

Figure 2 shows that the majority of respondents were aware of e-waste and its recycling, totaling 205, while only 35 had no prior knowledge. This indicates a generally high level of awareness among the respondents, reflecting the effectiveness of existing information channels and exposure to environmental issues related to electronic waste. However, the presence of a knowledge gap among part of the population underscores the need for ongoing awareness and education to promote proper e-waste recycling practices.

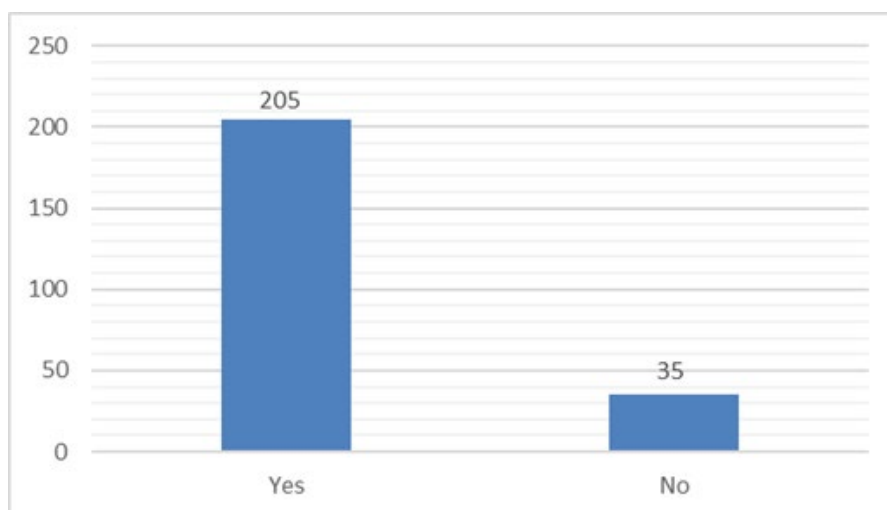


Figure 2: Level of knowledge on e-waste.

This finding is consistent with previous studies, which reported that although respondents recognized that electrical and electronic devices contribute to environmental problems, many lacked sufficient knowledge of appropriate e-waste recycling methods. Similarly, even a long time

ago, respondents in Shah Alam demonstrated good general knowledge of e-waste but were less familiar with proper recycling procedures [4]. These findings suggest that public awareness often focuses on recognizing environmental issues rather than understanding practical recycling practices.

Furthermore, Rosa & Collado [5] argued that environmental awareness is influenced by psychological factors, including personal values and the influence of family, friends, and social networks. This may explain the relatively high awareness observed in the present study, as individuals exposed to environmentally responsible attitudes in their social environment are more likely to recognize the importance of e-waste management. Therefore, future awareness programs should focus not only on increasing general knowledge but also on improving practical understanding of e-waste recycling methods and available collection facilities.

3.3 Perceived Importance of E-Waste Recycling to the Environment

Figure 3 reveals respondents' perceptions of the importance of e-waste recycling for environmental protection. The results show that an overwhelming majority of respondents (235 respondents) considered e-waste recycling to be important, while only 5 respondents perceived it as unimportant. This finding demonstrates a strong consensus regarding the role of e-waste recycling in reducing environmental pollution and conserving natural resources.

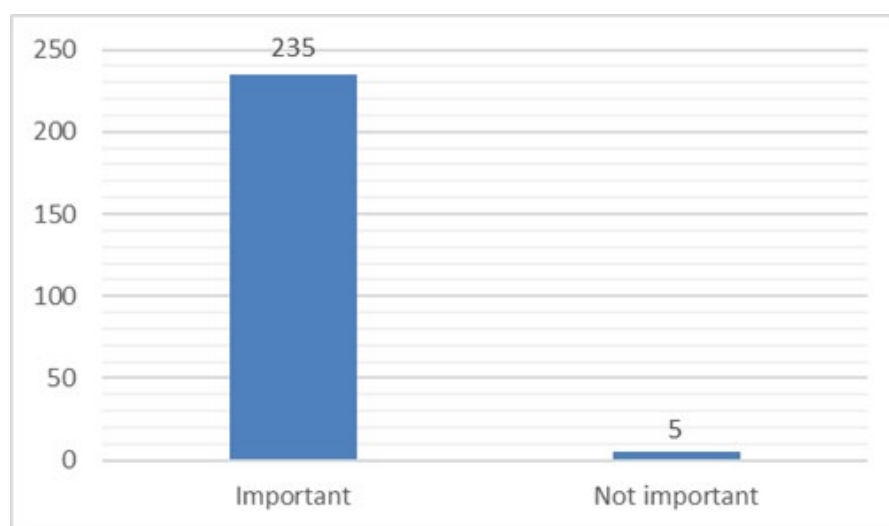


Figure 3: The importance of e-waste recycling to environment

The high level of perceived importance suggests that respondents are generally aware of the environmental risks associated with improper disposal of e-waste, including soil and water contamination and the release of hazardous substances. This positive perception may be attributed to increased environmental education, media exposure, and public awareness campaigns that promote sustainable waste management practices. Such awareness is encouraging, as recognizing the importance of environmental protection is often the first step towards adopting pro-environmental behavior.

The present finding is consistent with the earlier results of this study, which demonstrated a high level of awareness regarding e-waste and its environmental impacts. Similarly, Yeow & Low [6] reported that individuals with stronger environmental awareness were more likely to engage in recycling activities, suggesting that positive environmental attitudes can encourage sustainable behavior. However, despite the high level of perceived importance observed in the present study, actual participation in e-waste recycling remained relatively low. This indicates that awareness alone is insufficient to promote consistent recycling practices and that practical barriers, such as limited access to recycling facilities and insufficient recycling infrastructure, continue to influence

public behavior. Therefore, policymakers should complement awareness campaigns with improved recycling infrastructure, accessible collection centers, and continuous public education to bridge the gap between environmental awareness and actual recycling practices.

3.4 Awareness of the Significance of E-Waste Recycling

Although previous studies have reported that public awareness of e-waste and its hazardous components remains relatively low in Malaysia, the present study found that 183 respondents were aware of the significance of e-waste recycling, suggesting an improvement in public awareness, as shown in Figure 4. This indicates a relatively high level of awareness regarding proper e-waste management. This finding suggests that public exposure to environmental information through educational institutions, mass media, and awareness campaigns has contributed positively to increasing knowledge of e-waste recycling. However, 37 respondents were unsure about e-waste recycling practices, while the remaining 20 were not aware at all, indicating that knowledge gaps remain within the community. This uncertainty may arise from a limited understanding of proper recycling procedures, collection facilities, and the distinction between general waste and e-waste, which can discourage active participation in recycling.

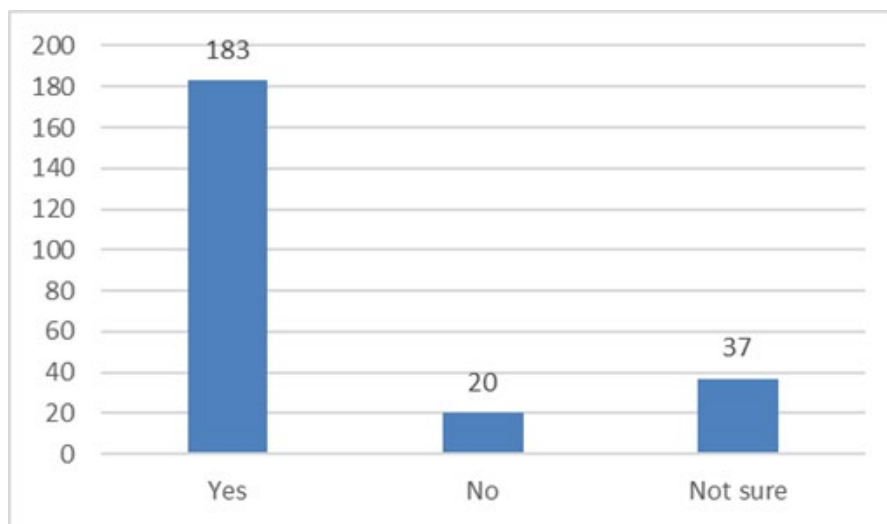


Figure 4: The awareness of e-waste recycling among respondents.

The findings of this study are consistent with Hamzah et al. [7], who reported that recycling culture among Malaysians remains relatively low due to insufficient public exposure and limited knowledge of recycling practices. Similarly, Nur et al. [8] emphasized that greater public education is essential to improve community attitudes and encourage responsible recycling behavior. Although respondents in the present study demonstrated relatively high awareness of e-waste recycling, the findings suggest that awareness alone is insufficient to ensure consistent recycling practices.

This observation is further supported by Sultan et al. [9], who found that many individuals were reluctant to regard stored electronic devices as e-waste and perceived the recycling process as inconvenient and time-consuming. Participants also highlighted a lack of awareness programs and limited access to disposal facilities, leading many to store unwanted electronic devices at home rather than properly recycle them. These findings support the present study by suggesting that practical barriers, in addition to knowledge gaps, continue to hinder effective e-waste recycling despite increasing public awareness.

Therefore, improving e-waste management requires more than awareness campaigns alone. Policymakers and relevant stakeholders should strengthen community education programs while simultaneously expanding accessible collection centers, providing clear recycling

guidelines, and implementing convenient collection initiatives. Such integrated efforts are essential to translate public awareness into consistent recycling behavior and support sustainable e-waste management.

3.5 Sources of E-Waste-Related Information

Figure 5 summarizes the main sources through which respondents obtained information about e-waste and recycling methods. The results show that schools and universities (99 respondents) and social media, television, and radio (95 respondents) are the dominant sources of information. This finding highlights the significant role of formal educational institutions and mass media in disseminating knowledge related to e-waste management and recycling practices. Educational institutions provide an effective platform for introducing environmental concepts at an early stage, while mass media enable information to reach a broader segment of the population.

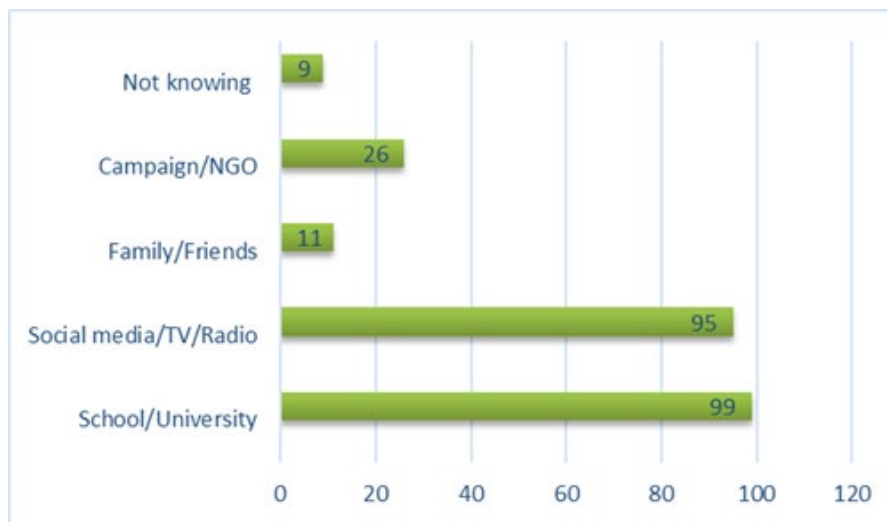


Figure 5: The source of e-waste knowledge and information.

The present findings are consistent that educational programs in schools and public awareness campaigns are essential for improving public knowledge and increasing participation in e-waste recycling [8]. Similarly, Kamaluddin et al. [10] reported that planned environmental awareness activities positively influence community engagement in e-waste recycling practices. These findings suggest that combining formal education with well-designed awareness programs can effectively promote responsible e-waste management.

In contrast, campaigns conducted by non-governmental organizations (NGOs) were identified by only 26 respondents, while family and friends were cited by 11 respondents. This indicates that although community-based initiatives contribute to public awareness, their influence remains considerably lower than that of educational institutions and mass media. Pariatamby & Bhatti similarly highlighted that continuous environmental education through mass and electronic media is necessary to ensure that environmental messages are effectively communicated and understood by the public [11]. Furthermore, Aboelmaged suggested that individuals who consistently practice recycling can positively influence the behavior of those around them, indicating that interpersonal communication can complement, rather than replace, formal awareness initiatives [12].

Notably, nine respondents reported having no source of information on e-waste recycling, indicating that certain groups remain beyond the reach of existing awareness programs. This finding suggests that current communication strategies may not adequately reach all segments of society, particularly those with limited access to educational institutions or digital media. Therefore, policymakers should adopt a more integrated communication strategy by

strengthening collaboration between government agencies, educational institutions, media organizations, and community groups. Expanding community-based campaigns alongside formal educational programs would improve the dissemination of e-waste information and encourage greater public participation in sustainable recycling practices.

3.6 Participation in E-Waste Recycling Practices

Among the 240 respondents, an equal distribution was observed: 50% reported participating in e-waste recycling, while the remaining 50% reported no participation (Figure 6). This equal distribution indicates a clear gap between awareness and actual recycling behavior. Although previous findings in this study revealed high levels of awareness regarding the importance of e-waste recycling, only half of the respondents translated this awareness into practice. This suggests that factors beyond knowledge, including accessibility of recycling facilities, convenience, time constraints, and limited guidance on proper disposal methods, continue to influence recycling participation.

The present finding is consistent with Sultan et al., who identified several barriers to e-waste recycling, including concerns over personal data security, perceived monetary value of old electronic devices, emotional attachment to products, lack of awareness programs, and the complexity of the disposal process [9]. These barriers may explain why respondents who recognize the importance of e-waste recycling still choose to store unused electronic devices rather than dispose of them through appropriate recycling channels.

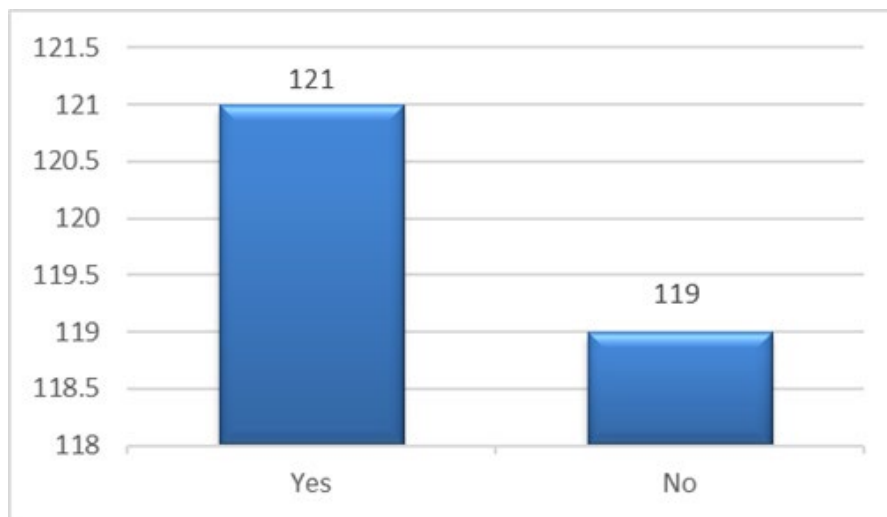


Figure 6: The experience and participation in e-waste recycling.

Similarly, Pariatamby & Bhatti emphasized that improving recycling participation requires not only public awareness but also adequate infrastructure and convenient collection facilities [11]. This recommendation is reflected in initiatives such as Maxis' e-waste recycling campaign, which expanded from collection services in selected cities to a nationwide postal drop-off program in collaboration with Electronic Recycling Through Heroes (ERTH). Such initiatives demonstrate how accessible and convenient collection systems can encourage greater public participation in responsible e-waste disposal.

Overall, the findings suggest that awareness alone is insufficient to promote consistent recycling behavior. A more comprehensive approach that combines continuous public education with accessible collection facilities, convenient recycling services, and supportive government-industry collaboration is needed to bridge the gap between awareness and practice. These measures would contribute to more effective e-waste management and support sustainable environmental development.

3.7 Methods and Practices of E-Waste Recycling

According to Mawardi et al., the Malaysian government has collaborated with the National Solid Waste Management Department (NSWMD) to improve the collection of household e-waste by establishing designated collection centers listed on the Department of Environment (DOE) website [13]. These initiatives are intended to provide the public with accessible and reliable channels for proper e-waste disposal. Figure 7 presents the preferred methods of e-waste recycling among the respondents. The most preferred method was sending or selling e-waste to third-party recyclers, followed by disposing of e-waste at licensed recycling centers. Participation in office- or school-based recycling programs was also common, while a smaller proportion of respondents reported using other disposal methods. These findings suggest that respondents generally favor recycling options that are convenient, accessible, and supported by established collection systems.

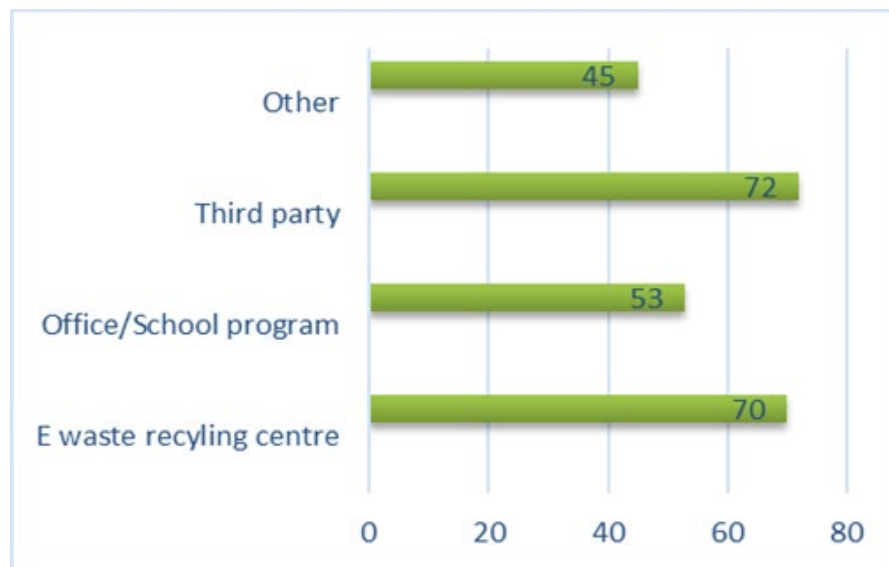


Figure 7: The methods and practices of e-waste recycling.

The present findings are consistent with Mawardi et al., who highlighted that improving access to authorized collection centers can encourage greater public participation in e-waste recycling [13]. The preference for third-party recyclers and licensed recycling centers observed in this study indicates that respondents are more likely to recycle when suitable disposal facilities are readily available. Similarly, participation in office and school recycling programs demonstrates the important role of educational institutions and workplaces in promoting environmentally responsible behavior by providing organized and trusted recycling channels.

Overall, the findings suggest that accessibility and convenience are key factors influencing respondents' choice of e-waste recycling methods. Therefore, efforts to improve e-waste recycling should focus not only on increasing public awareness but also on expanding authorized collection centers, strengthening institutional recycling programs, and improving collaboration among government agencies, educational institutions, and private recycling companies. Such measures would help increase public participation in formal e-waste recycling and support sustainable waste management in Malaysia.

3.8 Barriers to E-Waste Recycling

Figure 8 presents the main barriers to e-waste recycling identified by the respondents. The most frequently reported barrier was limited knowledge of authorized e-waste recycling centers, identified by 84 respondents. This was followed by the perception that recycling centers were

located too far from respondents' residences (58 respondents), indicating that accessibility remains a significant challenge. In addition, 33 respondents reported insufficient understanding of the importance and environmental implications of e-waste recycling, while 22 respondents cited a lack of time as the primary reason for not recycling. The remaining 40 respondents identified other personal reasons. Collectively, these findings indicate that informational and infrastructural barriers have a greater influence on e-waste recycling behavior than a lack of environmental concern.

The present findings are consistent with Azlan et al. [14] who highlighted that increasing public awareness alone is insufficient to encourage responsible e-waste disposal when convenient recycling facilities and adequate incentives are lacking. Similarly, Noor et al. emphasized that information on authorized e-waste collection centers should be made easily accessible to the public to facilitate proper disposal practices [8]. The agreement between these studies and the present findings suggests that improving public access to reliable recycling information is as important as increasing environmental awareness. Furthermore, the findings indicate that practical barriers continue to discourage public participation despite generally positive attitudes towards e-waste recycling. Singhal et al. argued that recycling systems should be simple, convenient, and easily accessible to encourage sustainable recycling behavior [15]. Likewise, Ahirwar & Tripathi demonstrated that incentive-based programs and community participation initiatives can effectively motivate individuals to recycle e-waste [16]. In addition, Pariatamby & Bhatti highlighted the importance of continuous environmental education and innovative public awareness strategies to reinforce responsible waste management practices [11]. These studies collectively support the present findings by demonstrating that improving infrastructure, accessibility, and public engagement is essential for increasing participation in e-waste recycling.

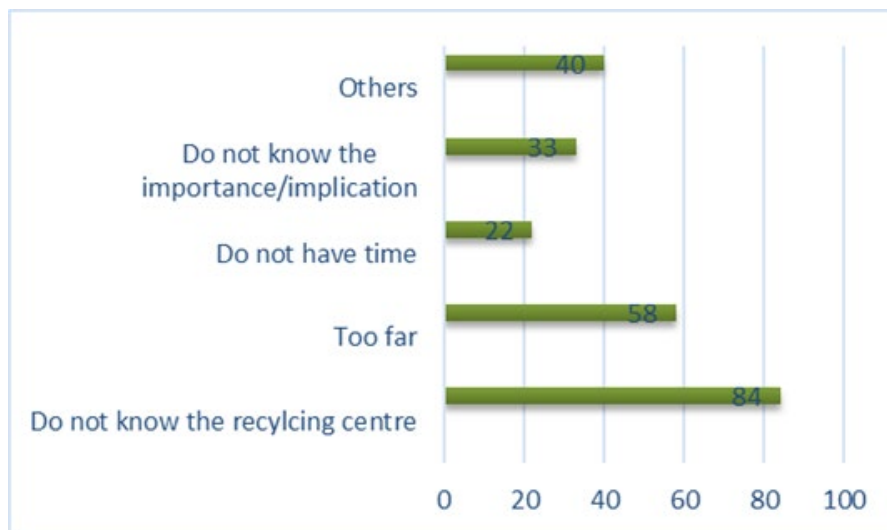


Figure 8: The barriers for not interested on recycling e-waste.

Overall, the findings suggest that addressing e-waste recycling challenges requires a comprehensive approach that extends beyond awareness campaigns. Policymakers should prioritize expanding authorized collection centers, improving public access to information on recycling facilities, and implementing continuous educational programs alongside community-based initiatives and incentive schemes. Such integrated efforts would help bridge the gap between environmental awareness and recycling behavior, thereby promoting sustainable e-waste management and supporting the achievement of Sustainable Development Goals (SDGs) 3 (Good Health and Well-being), 6 (Clean Water and Sanitation), and 11 (Sustainable Cities and Communities).

3.9 Frequency of E-Waste Recycling Activities

Figure 9 presents the frequency of e-waste recycling among the respondents. The findings indicate that regular participation in e-waste recycling remains relatively low. A total of 90 respondents reported never having recycled e-waste, while 85 reported seldom participating in e-waste recycling activities. In comparison, 58 respondents reported occasionally recycling e-waste, whereas only 5 reported frequently recycling e-waste. These findings suggest that although respondents generally recognize the importance of e-waste recycling, consistent recycling behavior has not yet become a common practice.

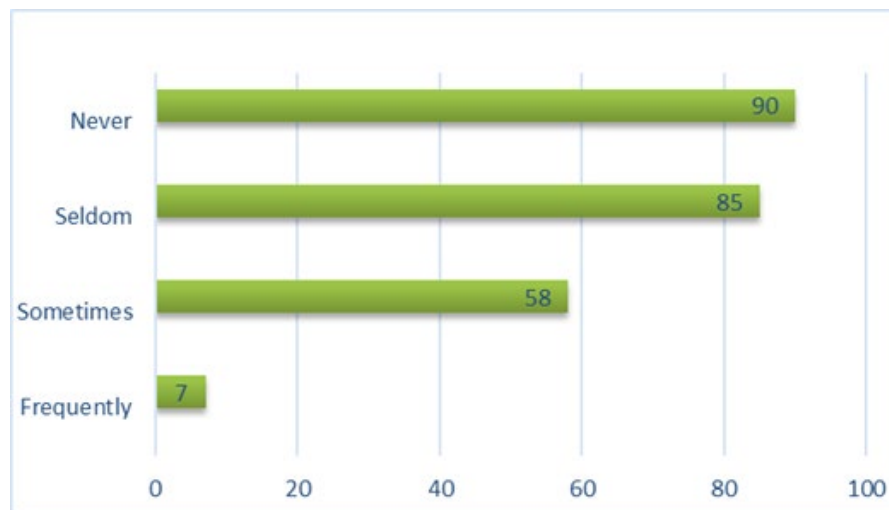


Figure 9: The frequency of recycling e-waste for the respondents.

The present findings are consistent with Mawardi et al. , who reported that Malaysia's e-waste recycling rate remains relatively low due to inadequate recycling infrastructure and limited public awareness [13]. Similarly, Azlan et al. observed that although awareness of e-waste has improved, many individuals continue to dispose of e-waste improperly due to limited access to recycling facilities and insufficient motivation to recycle. These findings indicate that awareness alone is insufficient to promote regular recycling behavior without adequate institutional support and convenient recycling systems [14].

The findings also support the behavioral perspectives reported by Dhir et al. and Yadav et al. Dhir et al. demonstrated that individuals are more likely to participate in e-waste recycling when they observe similar behavior within their community [17], whereas Yadav et al. found that poor recycling practices among neighbors can discourage others from recycling [18]. This suggests that social influence plays an important role in shaping recycling behavior and may partly explain the low frequency of e-waste recycling observed in the present study.

Furthermore, the low recycling frequency observed in this study may also be associated with the barriers identified earlier, including limited knowledge of authorized recycling centers, perceived distance to collection facilities, time constraints, and insufficient understanding of the environmental consequences of improper e-waste disposal. These findings highlight that both behavioral and infrastructural factors influence public participation in e-waste recycling.

Overall, the results suggest that increasing public awareness alone is unlikely to achieve sustained improvements in e-waste recycling behavior. Policymakers should therefore strengthen recycling infrastructure, improve access to authorized collection centers, expand community-based recycling programs, and encourage positive social norms through continuous education and public engagement. Such integrated strategies would help transform

environmental awareness into regular recycling practices and contribute to sustainable e-waste management in Malaysia.

3.10 Self-Awareness Level in Practicing E-Waste Recycling

Figure 10 presents respondents' self-perceived awareness of e-waste recycling. The findings indicate varying levels of awareness among the respondents. A total of 94 respondents rated their awareness as good, while 90 rated it as moderate, suggesting that most respondents believed they had a reasonable understanding of e-waste recycling. In contrast, only 18 respondents rated their awareness as very good, whereas 28 respondents and 10 respondents reported weak and very weak awareness, respectively. These findings indicate that although respondents generally perceive themselves to be aware of e-waste recycling, confidence in their knowledge varies across the population.

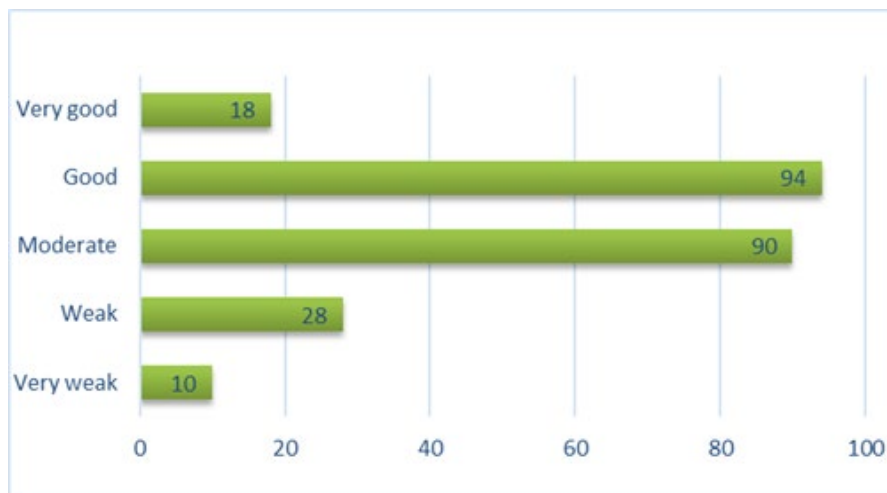


Figure 10: The self-awareness level for the respondents.

The present findings are consistent with those of Mahat et al., who reported that e-waste management in Malaysia remains at an early stage, particularly in recycling systems, management practices, and public participation [19]. Similarly, the present study found that although many respondents perceived their awareness as good or moderate, previous findings showed relatively low recycling participation and identified several barriers, including limited knowledge of recycling centers and insufficient practical guidance. This suggests that self-perceived awareness does not necessarily translate into consistent recycling behavior.

These findings highlight the need for educational programs that extend beyond raising general awareness to developing practical knowledge and confidence in e-waste recycling. Public awareness initiatives should provide clear information on recycling procedures, authorized collection centers, and the environmental consequences of improper e-waste disposal. Strengthening practical knowledge alongside accessible recycling infrastructure would help improve public participation in e-waste recycling and support more sustainable waste management practices.

3.11 Recommendations for Improving Public Awareness and E-Waste Recycling Practices

Figure 11 presents respondents' recommendations for improving public awareness and e-waste recycling practices. The most strongly supported recommendation was the implementation of e-waste awareness campaigns, selected by 96 respondents, indicating that respondents perceive continuous public education as the most effective strategy for promoting responsible e-waste recycling behavior. This finding highlights the importance of sustained awareness initiatives in

improving public understanding of the environmental and health risks associated with improper e-waste disposal.

The establishment of additional e-waste collection centers was the second most frequently recommended measure, supported by 78 respondents. This finding is consistent with earlier results in the present study, where limited knowledge of recycling centers and accessibility were identified as major barriers to recycling participation. Noor et al. similarly emphasized that strengthening recycling infrastructure, promoting source segregation, and improving collection systems are essential for increasing public participation in e-waste recycling [3]. These findings suggest that improving accessibility should accompany awareness campaigns to encourage sustainable recycling practices [20].

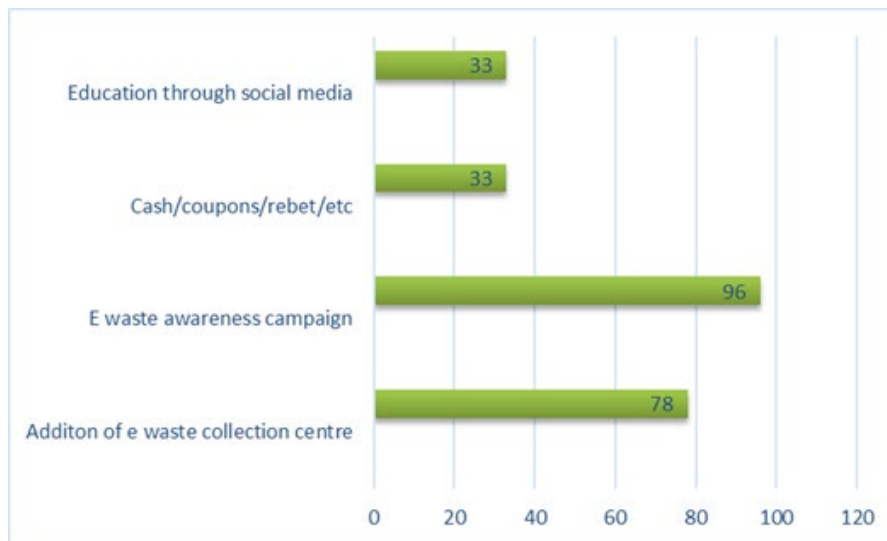


Figure 11. Recommendations for improving public awareness and e-waste recycling in Perlis.

In comparison, education through social media and financial incentives, such as cash rewards, coupons, or rebates, received lower support, with 33 respondents selecting each option. Although these strategies may complement existing initiatives, respondents clearly prioritized system-level interventions, particularly awareness campaigns and improved recycling infrastructure, over incentive-based approaches. The present findings are also consistent with Sultan et al., who reported that effective e-waste management requires coordinated efforts at the individual, organizational, and governmental levels [9]. Their study highlighted the importance of awareness campaigns, accessible disposal facilities, appropriate incentives, and stronger policy enforcement to encourage responsible e-waste disposal. Similarly, the present study demonstrates that respondents place greater emphasis on government-supported awareness programs and improved recycling infrastructure than on financial incentives alone.

Overall, the findings of this study indicate that improving e-waste recycling requires an integrated approach that combines continuous public education, accessible recycling infrastructure, supportive government policies, and collaboration among educational institutions, industry, and local communities. These recommendations not only address the barriers identified throughout this study but also provide practical guidance for policymakers and stakeholders in designing more effective e-waste management strategies. Implementing these measures would strengthen public participation in e-waste recycling and contribute to achieving sustainable waste management.

4. CONCLUSION

This study examined public awareness, perceptions, participation, and practices regarding e-waste recycling, as well as the barriers to and recommendations for improving e-waste management. The findings reveal that while respondents generally demonstrate high awareness and positive perceptions regarding the importance of e-waste recycling for environmental protection, actual recycling practices remain limited and inconsistent.

The demographic analysis shows that younger and working-age groups dominate the respondent profile, suggesting greater exposure to electronic devices and related information. A high proportion of respondents are knowledgeable about e-waste and strongly acknowledge its environmental importance. However, this awareness does not consistently translate into active or frequent recycling behavior. Participation results indicate that only half of the respondents have engaged in e-waste recycling, with the majority reporting low frequency of recycling activities.

The study further identifies informational and infrastructural barriers as the primary challenges to effective e-waste recycling. Most respondents reported not knowing the location of recycling centers or perceiving them as inaccessible, while others cited time constraints and limited understanding of the implications of improper e-waste disposal. These barriers highlight a clear gap between awareness, intention, and action. Although respondents reported moderate to good self-awareness of e-waste recycling, fewer individuals expressed high confidence in their knowledge and practices, indicating that awareness may be superficial rather than practical.

In terms of recycling methods, respondents preferred accessible and convenient options such as third-party services, recycling centers, and institutional programs at schools or workplaces. This underscores the importance of structured systems and accessible facilities in encouraging proper recycling behavior. Moreover, respondents identified e-waste awareness campaigns and the expansion of collection centers as the most effective strategies for improving public engagement, while financial incentives and social media education were considered supportive but less critical.

To conclude, the findings suggest that improving e-waste recycling requires more than awareness alone. Integrated approaches combining public education, accessible infrastructure, and supportive policies are essential to bridge the gap between knowledge and practice. The results provide valuable insights for policymakers, educational institutions, and environmental stakeholders to design targeted interventions that strengthen participation in e-waste recycling and support long-term sustainable waste management.

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