

# Comprehensive Assessment of Waste Electrical and Electronic Equipment Generation and Management Practices in Zamboanga City, Philippines: Basis for Policy Recommendations

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## Abstract

According to the advancement of technology and the environmental and safety challenges associated with waste electrical and electronic equipment (WEEE), this study assessed the management of WEEE in Zamboanga City, Philippines. The research found different trends of the WEEE generation that are industry-specific, with telecommunications and radio stations being the primary contributors. Lack of facilities, challenging regulations, and public awareness were identified as the main obstacles by qualitative analysis employing surveys, focus group discussions, and waste characterization reports. The research recommended public awareness campaigns, enhanced policies, stakeholder collaboration, and customized management strategies. These sought to guarantee responsible handling, reduce risks to the environment and public health, and establish a sustainable WEEE management system. The findings of this study were very helpful in creating Zamboanga City's evidence-based WEEE policies.

**Keywords:** Environmental Impact; Hazardous Waste Management; Public Awareness Campaigns; Sustainable Practices; Thematic analysis

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## 1. Introduction

The issue of waste electrical and electronic equipment (WEEE) emerged as a pressing global environmental concern, rapidly expanding and posing significant challenges for developing countries like the Philippines. In Zamboanga City, a bustling metropolis in Western Mindanao (Republic of the Philippines, 2020; Zamboanga City Local Sustainable Sanitation Plan Team, 2021), WEEE generation increased due to the rapid advancement of technology and

the growing popularity of electronic devices (Kitila & Woldemikael, 2019). Given the serious environmental and public health risks associated with improper disposal of this hazardous waste, a thorough evaluation of the city's WEEE management practices became necessary (Forti *et al.*, 2020; Mihai *et al.*, 2019; Yang *et al.*, 2020).

Zamboanga City, located in Western Mindanao, Philippines, developed into a thriving city serving as a major commercial

and industrial hub for various sectors like trade, commerce, transportation, communication, education, technology, tourism, and religion. The region flourished in producing commodities like fish and fish products, seaweeds, rubber, abaca, coconut, and mango (Department of Trade and Industry, 2023; Jain, 2017; Zamboanga City Local Sustainable Sanitation Plan Team, 2021). Industries such as agriculture, fishing, manufacturing, and tourism significantly contribute to the city's economic growth and employment opportunities (Brillo *et al.*, 2019; Ramos & Ridao, 2017; Yu *et al.*, 2020).

The data of DENR-EMB Region IX for Zamboanga City between 2020 and 2022 (EMB Region IX, 2020) revealed that industries producing the most WEEE included government and military institutions, wholesalers of liquid and gaseous fuel products, fishmeal production, fish cold storage and canning, ice production, cargo handling and passenger services for sea vessels, hospitals, radio stations, telecommunications, livestock production, beverage production and many others. As shown in Figure 1 (Kong *et al.*, 2023), factors affecting WEEE management practices in Zamboanga City included the availability and accessibility of WEEE collection and disposal infrastructure, relevant regulations and policies, and public perceptions.

Under the Department of Environment and Natural Resources (DENR), Administrative Order (AO) No. 2013-22 (Paje, 2013) requires industries to document and provide comprehensive details of waste movements, including WEEE. This regulatory framework aims to promote environmental sustainability and ensure compliance with standards to safeguard public health and the environment. However, challenges persist as there are no accredited Treatment, Storage, and Disposal (TSD) facilities in the region capable of handling hazardous WEEE components. All WEEE became categorized as a new class of miscellaneous waste in DENR, AO No. 2013-22, with waste numbers M506 (WEEE) and M507 (Special Waste) and including hazardous components (Hong Vu *et al.*, 2022; Paje, 2013; Tolentino *et al.*, 2023).

Informal electronic waste recycling workers often collect unwanted electrical and electronic equipment from homes and other locations where they are dumped (UNIDO, 2022). Despite the submission of Self-Monitoring Reports (SMRs) by industries to demonstrate environmental compliance, the city generated 22.4 tons of WEEE between 2020 and 2023 (Jimenez, 2022). This underscores the need for more effective management strategies and infrastructure.

This study aimed to comprehensively assess the historical generation and management of WEEE in Zamboanga City, Philippines, to inform policy recommendations. The specific objectives were to determine the types and quantities of WEEE generated, identify the sources of WEEE, and develop recommendations for improving WEEE management.

## 2. Methodology

The research methodology utilized in this study investigated the production, disposal methods, and awareness regarding Waste Electrical and Electronic Equipment (WEEE) in Zamboanga, Philippines' industries and establishments. Using Dawadi's (Dawadi, 2020) work as a guide, a qualitative thematic analysis approach was used to capture the richness and subtleties of the subject matter. Thematic analysis was employed to clarify respondents' viewpoints and experiences (Dawadi, 2020; Foroudi, Pantea; Dennis, 2024; Mihai *et al.*, 2019; Swain, 2018). It is recognized for its adaptability and efficacy in identifying recurrent themes and meanings within qualitative data.

The study specifically applied thematic analysis techniques that combined deductive and inductive reasoning (Naeem *et al.*, 2023; Proudfoot, 2023). The approach used a combination of deductive and inductive methods (Naeem *et al.*, 2023; Proudfoot, 2023). The inductive method used open-ended data collection techniques, such as administering open-ended questionnaires and reviewing waste characterization reports, to allow themes to emerge naturally without the need for pre-existing theoretical frameworks. Focus group discussions were also held to

encourage people from various industries to share their knowledge and experiences regarding WEEE management.

On the other hand, the deductive method directed the selection of focus group participants according to their capacity for WEEE generation and industry representation. Based on the current understanding of WEEE management strategies and obstacles, a structured questionnaire was created to guarantee that relevant data was gathered for examination.

A research framework examining Zamboanga City's management of Waste

Electrical and Electronic Equipment (WEEE) is shown in Figure 2. Using waste report analysis, major WEEE producers were identified. Diverse industries participated in focus groups to evaluate management awareness, environmental concerns, and WEEE generation practices. Data analysis revealed patterns and problems, guiding suggestions for stakeholders such as the government, corporations, and people. Through cooperation, Zamboanga City hopes to improve WEEE management and promote sustainability.

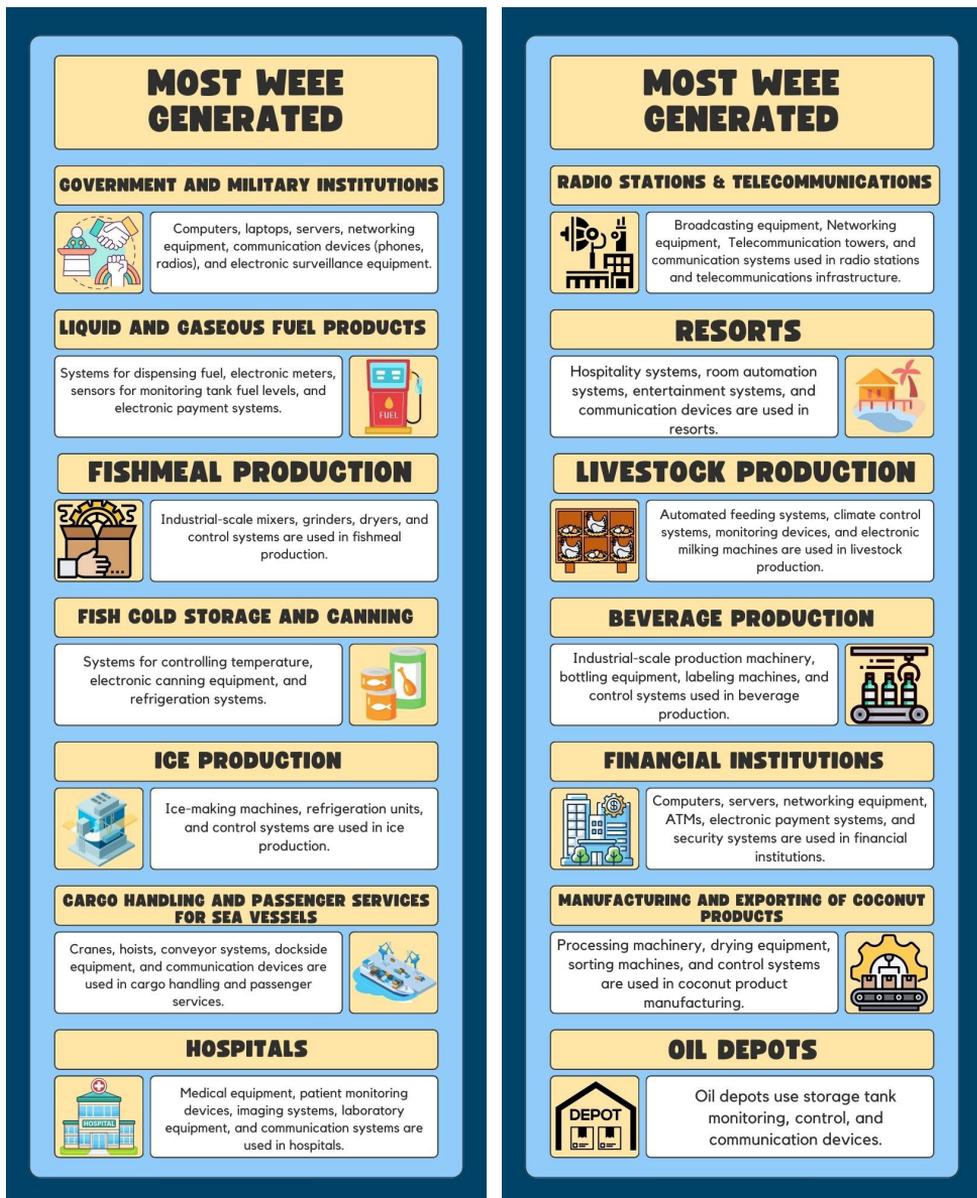
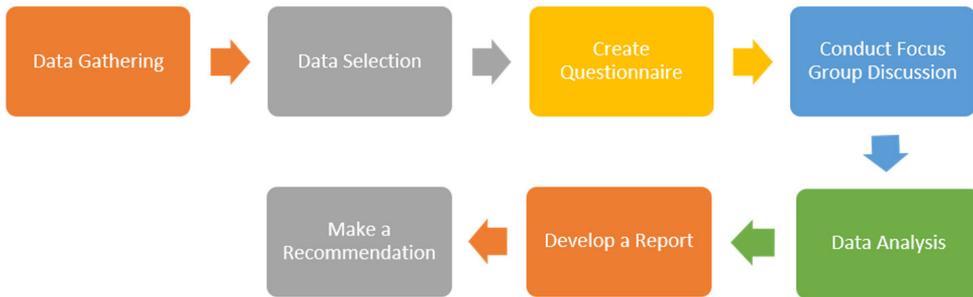


Figure 1. Most WEEE generated by the industries in Zamboanga City



**Figure 2.** Research framework

### 2.1 Data Gathering and Data Selection

Researchers obtained and examined waste characterization reports from DENR-EMB Region IX to identify businesses or industries generating significant amounts of WEEE. This analysis helped pinpoint the key players in WEEE production within the region.

A representative sample of businesses or industries was selected for a focus group discussion (FGD) (Msangi *et al.*, 2024; Nuwematsiko *et al.*, 2021). This selection considered the potential of each participant to generate WEEE and their representation across various industries. By ensuring a diverse group, researchers aimed to capture a broader perspective on WEEE management practices and challenges.

### 2.2 Focus Group Discussion Questionnaire

A key component of the Waste Electrical and Electronic Equipment (WEEE) management study in Zamboanga City, Philippines, was the Focus Group Discussion (FGD) questionnaire, which was developed using a qualitative thematic analysis framework (Dawadi, 2020; Swain, 2018). A representative sample of businesses underwent FGD selection after a waste characterization report analysis identified significant producers of waste electrical and electronic equipment (WEEE). This process took into account the industry representation as well as their potential to generate WEEE. In line with the study's goals, the customized questionnaire outlined in Figure 3 was sought to explore participants' disposal habits and awareness levels regarding WEEE generation patterns. These concerted efforts, which

included data analysis, focus group discussions, and targeted questionnaires, provided important new information about Zamboanga City's WEEE management procedures and awareness.

### 2.3 Focus group discussions (FGD)

A Focus Group Discussion (FGD) was held by researchers with a representative sample of businesses in Zamboanga City, Philippines. The researchers identified twelve (12) industries from the DENR EMB RIX list. Even though there were eight participants in the discussion, different viewpoints were sought. The FGD, which was facilitated by a researcher, allowed participants to freely discuss their experiences with WEEE management. The recorded conversation offered valuable perspectives and obstacles for examination and record-keeping. Researchers were able to extract important themes and insights from this recording, which was a useful resource that helped them gain a thorough understanding of Zamboanga City's WEEE management practices.

### 2.4 Data Analysis

Following the Focus Group Discussion (FGD), researchers conducted a qualitative analysis of the recorded conversation and associated notes. This analysis aimed to identify key themes and emerging issues related to WEEE management practices within the participating industries. By carefully examining the collected data, researchers were able to unveil recurring patterns and topics that shed light on the participants' experiences, challenges, and perspectives on WEEE management in Zamboanga City.

2.5 Report and Recommendations

This research, employing a qualitative thematic analysis approach (Proudfoot, 2023), investigated WEEE management in Zamboanga City, Philippines. It explored generation, disposal practices, and awareness levels among various industries and establishments.

Focus groups with specific industries were conducted after researchers identified the largest producers of WEEE by analyzing waste reports. They created customized surveys to gain more in-depth knowledge. The foundation for comprehending WEEE practices in the city was established by this method. Researchers identified important themes and issues after going over the focus group recordings and notes. A report summarizing their findings and offering suggestions for enhancing Zamboanga City’s WEEE management was produced. These suggestions were aimed at companies, trade groups, and government departments. The focus group discussions were carefully facilitated, and this resulted in the collection of insightful qualitative information that will be useful

for further research on sustainable WEEE management.

3. Results and Discussion

Effective management requires an understanding of the movement of waste electrical and electronic equipment (WEEE) in Zamboanga City. Through focus group discussions, this study investigates the generation of WEEE from industries such as manufacturing, retail, healthcare, and tourism. Gaps in our knowledge of WEEE generation are highlighted by official data from DENR Region IX (Jimenez, 2022). The study emphasizes the value of in-depth research for improved waste management plans in the area.

With 1.340 tons produced in 2020, the “wholesale of fuel” sector led the way in WEEE generation, followed by military and government institutions. 1.864 tons in total.

WEEE generation fell significantly in 2021 compared to 2020. The maintenance of ships may have contributed to the maritime industry’s major role. Shown in Table 2 that the fuel industry was missing, but hospitals and fish processing made contributions as well.

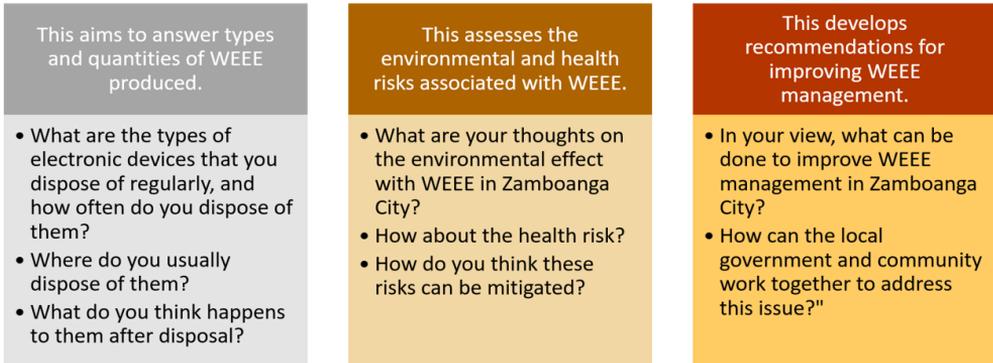


Figure 3. Questionnaire during focus group discussion

Table 1. 2020 WEEE generated in Zamboanga city

Industry in Zamboanga City	Tons
Government Institution	0.412
Military Institution	0.112
Wholesale of liquid and gaseous fuel products (PSIC - 46610)	1.340
Total WEEE for 2020	1.864

The WEEE generation landscape underwent a significant shift in 2022 shown in Table 3, with radio stations overtaking the fuel sector as the largest contributor with a production of 14.600 tons. The maritime industry's share decreased. The industries that produced the least were telecommunication and fish processing, with real estate and livestock production making up the majority. The need for focused management strategies is highlighted by the rise in WEEE generation overall, especially for significant contributors like radio stations and fish processing.

Different WEEE management practices were revealed by industry-specific surveys shown in Table 4 during focus group discussions. Hospitality establishments usually reused or repaired equipment, whereas retail stores and hotels favored reselling. Recycling was mostly used for material recovery in the manufacturing and fishing sectors. Some respondents used or stored out-of-date equipment, underscoring the need for better disposal techniques and raising awareness.

**Table 2.** 2021 WEEE generated in Zamboanga city

Industry in Zamboanga City	Tons
Production of Fishmeal for animal feed, Cold storage, preparation, and preserving of fish (Canning)	0.003
Manufacture of Ice (PSIC - 1079)	0.006
Processing, preserving, and canning of fish (PSIC - 15139)	0.006
Fish Canning and Fish Meal Plant (PSIC- 107)	0.038
1. Sea Vessel Docking & Anchoring (Mooring and Anchoring); 2. Caters Outbound and Inbound Passengers; 3. Cargo Handling, Stevedoring, Storage. (PSIC - 681)	0.248
Hospital	0.198
Radio Station	0.014
Total WEEE for 2021	0.513

**Table 3.** 2022 WEEE generated in Zamboanga city

Industry in Zamboanga City	Tons
Telecommunication	3.000
Fish Canning and Fish Meal Plant (PSIC- 107)	0.170
Livestock Production (PSIC - 14)	0.0015
Production of Fishmeal for animal feed, Cold storage, preparation, and preserving of fish (Canning)	2.001
Manufacture of Ice (PSIC - 1079)	0.003
Beverage Manufacturing (PSIC -1104)	0.007
Financial Institution (PSIC - 55)	0.0083
Radio station	14.600
Real Estate Activity with owned or leased property	0.0001
Fuel Refilling station	0.0002
Manufacturer / Exporter of Coconut Products	0.130
Oil Depot	0.025
Resort and other tourism/leisure projects	0.025
Product Merchant Wholesaler Industry	0.002
Wholesale of liquid and gaseous fuel products (PSIC - 46610)	0.0125
1. Sea Vessel Docking & Anchoring (Mooring and Anchoring); 2. Caters Outbound and Inbound Passengers; 3. Cargo Handling, Stevedoring, Storing. (PSIC - 681)	0.030
Financial Institution	0.001
Hotel	0.006
Total WEEE for 2022	20.023

The investigation’s goals regarding WEEE in Zamboanga City are clarified by the thematic analysis findings, which are shown in Tables 5 to 10. The study’s objective was to evaluate WEEE generation and management practices by using data analysis and focus group discussions to uncover important themes and insights. It underlined how crucial collaboration, stricter laws, and increased public knowledge of sustainable waste and energy management techniques are.

The eight participants in this result and discussion were coded as Respondent 1, Respondent 2, Respondent 3, Respondent 4, Respondent 5, Respondent 6, Respondent 7 and Respondent 8.

*WEEE generation and quantities*

Table 5 highlights how critical it is to comprehend the patterns of e-waste generation and put comprehensive management strategies into place, with a focus on effective storage, teamwork, and legal compliance. Understanding e-waste’s generation dynamics is essential for effective management. Prior studies highlight the need for better management practices everywhere (Andeobu et al., 2021; Liu et al., 2022). Although a recent study conducted in Xiamen, China, provides insights using a novel model (Ismail & Hanafiah, 2021; Kariwala et al., 2023), there is a lack of specific data regarding e-waste in Zamboanga City. To address the city’s e-waste challenges, more research is required to determine the types and volume of e-waste generated there.

**Table 4.** Industry-specific surveys during the FGD

FGD Participants	Type of Industry	Role of industry in the WEEE process	How do you dispose of your WEEE?
1	Health Care	Refurbish, Dismantle, Recycle	Re-sell
2	Health Care	Use	Recycle (material recovery)
3	Hotel Industry	Use	Re-sell, Give Away
4	Shopping Center	Recycle	Re-sell, handled by an accredited DENR hauler
5	Fishing Industry	Use	Recycle (material recovery)
6	Health Care	Recycle	Recycle (material recovery)
7	Fishing Industry	Use	Recycle (material recovery)
8	Manufacturing	Use	Store at hazardous waste storage

**Table 5.** Types and quantities of WEEE generated in Zamboanga city

Theme	<i>What are the types of electronic devices that you dispose of regularly, and how often do you dispose of them?</i>
WEEE Generation and Quantities	<p>Respondents 1 and 2: They operate as a product exporter and diversified into sardine-related product lines. The supervisor's role here focuses on contributing ideas to waste management.</p> <p>Respondents 3 and 4: Address a significant volume of sharps and needle items, with e-waste management needing to be more urgent due to available storage areas. Functional computer setups and operational electronic devices characterize their approach.</p> <p>Respondent 5: Manages computer sets and laptops while complying with corporate commitments for waste management. The facility collects used parts waste from Cyberzone stores and stores 820 kg of e-waste in the Material Recovery Facility (MRF), including 72 kg of faulty lights.</p>

*Current E-waste management practices*

According to Table 6, a study on Zamboanga City’s e-waste management reveals a complicated system with numerous stakeholders. Responsible disposal presents several challenges, including converting hazardous materials, working with outside companies, and expensive transportation. Rules and professional guidance are necessary for managing this kind of waste. The city’s strategy combines the formal and informal sectors (Campuzano & Crisanto, 2020; Widiyanto, 2019b), with a Material Recovery Facility for collection and tenants handling (Elyta et al., 2021; Patil & Ramakrishna, 2020) e-waste in malls. Difficulties include hazardous waste from the sewage treatment plant and the sluggish disposal of LED lighting, though cooperation with Manila facilitates transfer to treatment facilities (Muliawaty, 2020).

*Challenges and barriers*

Table 7 outlines the complex issues surrounding Zamboanga City’s e-waste management and shows a possible way forward through cooperation. Diverse sectors working together give hope for sustainable solutions despite major obstacles like scarce infrastructure,

resources, and regulations (Patil & Ramakrishna, 2020; Rieck et al., 2022; Srivastava & Pathak, 2019). According to expert recommendations, legislation should be strengthened to include producer responsibility (Turaga et al., 2019) and better e-waste management education (Khetriwal, 2019). By removing these barriers, the risks to the environment and public health associated with inappropriate disposal of e-waste can be reduced and e-waste management become more efficient.

*Policy and regulatory framework*

To improve environmental sustainability regulations, Table 8 examines the effects of policies on e-waste management. Previous evaluations in Zamboanga City focused on improving laws to establish an all-encompassing system (Widiyanto, 2019a). Concerns such as irregular storage procedures led to a demand for standardized frameworks (Elyta et al., 2021). It was suggested to work with organizations such as the Armed Forces of the Philippines, highlighting the importance of group effort (Campuzano & Crisanto, 2020; Kurniawan et al., 2021).

**Table 6.** Existing WEEE management practices in Zamboanga city

Theme	<i>What do you know about WEEE management in Zamboanga City?</i>
Current E-waste Management Practices	<p>Respondents 5 and 7: Zamboanga City's e-waste management system once handled waste from both inside and outside the establishment, with tenants responsible for their own disposal. A Material Recovery Facility existed to collect waste, but hazardous waste from the sewage treatment plant posed a challenge. Collaboration with the Manila branch enabled the transfer of this waste for treatment.</p> <p>Respondents 3 and 4: Establishments in the past dealt with e-waste that included medical devices. They consulted experts on how to dispose of or repair these devices. Hazardous materials were treated to make them safer and then hauled to special treatment facilities, a complex and expensive process.</p>

**Table 7.** Assessing the environmental and health risks associated with WEEE

Theme	<i>How do you think these risks can be mitigated?</i>
Challenges and Barriers	<p>Respondents 3, 4, and 7: Grapples with hazardous waste management. Initial steps include identifying waste types and arranging proper disposal, an approach undertaken in coordination with nearby areas.</p> <p>Respondent 5: Deals with challenges posed by e-waste from both internal and external sources. The lengthy disposal process, particularly for LED lighting, raises questions about efficient solutions. Collaborative efforts with external solutions and logistical considerations for waste transfer are evident in their strategy.</p> <p>Respondent 6: Addresses challenges through repair prioritization over disposal, adhering to DENR’s regulations. Collaboration with potential recipients for reusable parts is practiced, highlighting the industry’s efforts toward resource conservation.</p>

**Table 8.** Legal aspect on WEEE

Theme	<i>Are there any ordinances, specific laws, or regulations in place for the collection, transportation, and disposal of WEEE in Zamboanga City?</i>
Policy and Regulatory Framework	<p>Respondents 7 and 8: Recognize the diversity in storage practices across companies and the potential benefits of a standardized policy and procedure framework are acknowledged. Collaboration with the Armed Forces of the Philippines (AFP) to devise a unified approach is considered, highlighting the importance of collective efforts to establish consistent and efficient e-waste management practices.</p>

**Table 9.** Proper management of WEEE

Theme	<i>What are the potential economic opportunities associated with the proper management of WEEE in the city?</i>
Informal E-waste Recycling Sector	<p>Respondents 1 and 2: Appreciate the measures taken to manage hazardous items, and emphasizing part reusability highlights a conscientious approach. Addressing various waste types, from wires to computers, underlines the comprehensive scope of responsible disposal practices</p> <p>Respondent 8: Acknowledges the significance of proper waste disposal, particularly concerning medical waste, and underscores the importance of environmental safety and regulatory adherence. The assistance in addressing waste management concerns aligns with a collective effort to enhance responsible practices.</p>

*Informal E-waste recycling sector*

As it promotes sustainable practices to lessen environmental harm, Table 9 highlights the importance of government cooperation and community involvement in efficient waste management. Sustainable e-waste management and responsible waste handling are encouraged

by placing a strong emphasis on partnerships, unambiguous regulations, and education. Research conducted in the past (Gbedemah & ZANETI, 2021; Moletsane, 2020; Shaikh *et al.*, 2020; Widiyanto, 2019a) emphasized the dangers that informal e-waste recyclers face and suggested ways to improve waste management systems.

**Table 10.** View of the general public regarding WEEE

Theme	<i>Can you describe the current state of awareness and knowledge of the general public regarding WEEE and its environmental impacts?</i>
Awareness and Education	Respondents 6 and 7: Acknowledge the indispensability of education, communication, and partnerships and echo the role of continuous awareness-building and stakeholder engagement. The imperativeness of maintaining a learning continuum, ensuring comprehensive comprehension of best practices, regulations, and environmental concerns, is emphasized.

*Awareness and Education*

Table 10 highlights the importance of government-business cooperation and education for sustainable e-waste management (Adeel et al., 2023), as per a study conducted in Zamboanga City. The study emphasized how important it is to have partnerships, clear regulations, and government support in order to achieve social and environmental benefits. Prior studies emphasized the need for management practices knowledge and education and awareness campaigns for safe e-waste disposal in addition to efficient disposal plans (Zamboanga City Local Sustainable Sanitation Plan Team, 2021). It was determined that cooperation and education were necessary to promote sustainable business practices and close knowledge gaps, especially for small and medium-sized enterprises (Sandhu, 2021).

*Summary of findings*

The research aimed to understand Zamboanga City’s WEEE flow, combining quantitative and qualitative data. It found varied WEEE management strategies among industries, some handling it internally while others relied on third parties due to awareness gaps and complex regulations. The study advocated teamwork and ethical management. Zamboanga’s proposed Environment Code aimed to bolster waste management (Panlungsod, 2019), promoting recycling and recovery at barangay levels. Incorporating specific WEEE guidelines into the E-Code could improve management through plans (Kong et al., 2023), corporate and NGO cooperation, and Extended Producer Responsibility programs.

The research results not only aid in comprehending Zamboanga City’s WEEE management practices but also provide valuable perspectives that can be applied to comparable urban environments worldwide. This allows for the development of evidence-based policies that promote environmental sustainability.

**4. Conclusion and Recommendation**

The creation and management of waste electrical and electronic equipment (WEEE) was the subject of a study carried out in Zamboanga City, Philippines. It discovered that different industries produced different amounts and sources of WEEE, with radio stations and the telecommunications industry being the most significant contributors in 2022. This calls for flexible management approaches. The Zamboanga City Environment Code (E-Code) needed to be amended. Stakeholder collaboration should be encouraged, infrastructure for handling WEEE should be invested in, public awareness campaigns should be launched, and enforcement actions should be taken to reduce risks to the environment and public health.

The study recommended proactive practice modification based on historical trends and emerging issues, emphasizing the need for ongoing research and monitoring in WEEE management. By ensuring the efficacy of strategies in addressing Zamboanga City’s changing electronic waste production and disposal landscape, such continuous evaluation would promote sustainable and ethical practices.

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