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Research Article

Inventory of Electronic Waste (E-Waste) and Residues in Junkshops: A Step Towards Residual Waste Management

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Abstract: The improper management of Waste Electrical and Electronic Equipment (WEEE) constitutes a critical global environmental challenge, with a significant proportion of e-waste ending up in landfills, posing substantial ecological and health risks. In the Philippines, particularly in areas like Marilao, many individuals rely on the recycling of e-waste for their livelihoods, primarily through junkshops and informal recycling networks. Despite providing economic benefits, these practices often result in substantial residual waste, exacerbating landfill overflow and environmental degradation. This study aims to establish a detailed e-waste inventory and propose practical strategies for improving residual waste management. This research used a mixed-method approach to collect data via surveys, interviews, and direct observations at selected junkshops in Marilao. The findings enabled a comprehensive categorization of e-waste based on economic value, highlighting "temperature exchange equipment" as the most economically valuable category while identifying "small IT and telecommunication equipment" as the least. Among the significant residual wastes identified were base/black plastics, styrofoam, and glass, which are commonly mishandled. The study proposes several management strategies, including partnerships with local governmental bodies and recycling companies to enhance recycling processes, improving dismantling techniques to reduce waste, and implementing rigorous waste segregation practices to prevent contamination and improve recycling rates. This expansion is critical for a more comprehensive understanding and monitoring of e-waste management practices, facilitating the development of more effective and sustainable waste management solutions. By adopting these strategies, junkshops and informal recyclers can optimize e-waste management, reducing environmental impact while maintaining economic viability.

Keywords: Dismantling Techniques; Environmental Impact; Recycling; Sustainable Practices; Waste Treatment.

1. Introduction

In today's society, the widespread reliance on electrical and electronic equipment (EEE) has profoundly enhanced the quality of life, representing a globally pervasive trend [1], [2]. However, the entire lifecycle of EEE, from production and usage to eventual disposal, has contributed to the proliferation of unsustainable practices [3], [4]. This has resulted in a substantial increase in Waste Electrical and Electronic Equipment (WEEE) on a global scale. According to the Global E-Waste Monitor (2020), the annual global use of EEE has consistently grown by 2.5 million metric tons (Mt), increasing WEEE production by 9.2 Mt since 2014. Projections indicate that this figure will rise to 74.7 Mt by 2030, underscoring the urgent need for effective management strategies and sustainable practices to mitigate the environmental impact associated with EEE lifecycle processes [5].

The European Commission's WEEE Directive 2012/19/EU, Annex III [6], categorizes EEE into six key groups, facilitating the management and disposal of electronic waste. These groups include temperature exchange equipment, screens and monitors, lamps, large equipment, small equipment, and small IT and telecommunication equipment. Each category explicitly outlines refrigerators, televisions, and mobile phones for efficient electronic waste management.

These EEE constitute a significant import in the Philippines, generating impressive revenue of over $3.51 billion in January 2022 [7]. During that same month, EEE

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accounted for the country's highest percentage of imported goods, making up 26% of the total imports [8]. Nevertheless, it is essential to highlight that in the Philippines, a law permits the import and trade of electronic waste from other countries due to its perceived value [9]. However, there is currently a lack of available data indicating the specific percentage of this electronic waste that contributes to the overall imports of EEE in the country.

E-waste is generally considered a valuable resource in many countries due to the presence of gold, silver, platinum, copper, aluminum, nickel, tin, zinc, lead, and iron [10]–[13]. The composition of e-waste can be determined by the type and age of the discarded item and its combination with other plastics and ceramics commonly used as coatings for electronic devices. This e-waste undergoes recycling processes for the Harve station of metals. During this process, the most frequently encountered heavy metals include hazardous ones like mercury, lead, cadmium, and nickel and valuable materials such as copper, platinum, and gold [14]–[16]. These metals are then harvested by e-waste recyclers to be bought by manufacturers to use as resources.

However, residual waste from recycling e-waste is inevitable in this metal harvesting process. According to Balaria [17], in dismantling e-waste, recyclable or valuable e-waste is separated from parts that are not. Approximately 79.10% of the segregated parts can be recycled, while the remaining 20.90% becomes residual waste destined for landfills. The leftover parts primarily consist of materials like polyurethane, ABS, PVC, and non-combustible items, of which 58.20% are glass. These residual wastes contribute to the problem of environmental pollution. If improperly recycled, it will leach into the environment, causing soil, water, and air pollution.

In many developing countries, most e-waste recycling units operate in the informal sector, often lacking advanced technology for efficient e-waste recycling. These informal recyclers struggle to mitigate environmental pollution associated with inefficient e-waste recycling practices [18], [19]. For instance, in Delhi, informal e-waste sectors are associated with poverty, lack of awareness of health risks in e-waste management, and rare use of personal protective equipment (PPE). This has resulted in occupational injuries, such as cuts or burns, and mild health issues among e-workers [20]. Studies have also shown that exposure to e-waste recycling locations can cause DNA damage in the population [21], [22].

The situation is the same in the Philippines. Some people heavily rely on e-waste as a source of income. These informal recyclers, particularly from cities in the National Capital Region (NCR), fill the gap left by the need for formal e-waste collection. Due to this problem, an e-waste recycling association called "Eco-waste Coalition" was formed in collaboration with UNIDO (United Nations Industrial Development Organization) and the Philippine Government and NGOs. This association provides training and fair compensation to e-waste recyclers, addressing the issue of informal e-waste recycling in the Philippines.

In Atom Araullo's documentary [23] titled "Baklas," the process of handling e-waste in the NCR is depicted. In this documentary, e-waste collectors engage in door-to-door pickups and purchase various e-waste items from households. They dismantle what they consider "safe" WEEE, such as electric fans, CPUs, and refrigerators. However, hazardous e-waste items, such as old televisions, remain untouched and are specifically collected and purchased by the eco-waste coalition. The hazardous e-waste is then transported to a facility equipped with machines designed to disassemble and extract valuable metals from these materials safely. On the other hand, the disassembled "safe" WEEE is taken to junkshops for further processing [23].

Junkshops are widespread throughout the Philippines and operate as simple businesses involved in the buying and selling of solid waste. According to the Department of Trade and Industry's 2010 definition [24], a junkshop buys and sells scrap materials. These junk shops can source scrap materials from wholesale suppliers or receive them from scavengers, offering incentives in return. These junk shops later sell the collected scraps to recycling centers, transforming them into valuable resources. Often, the junk shops dismantle the collected scraps themselves, extracting the beneficial parts of the WEEE and selling them afterward. However, a problem arises because the residual waste from dismantling contributes to more trash in landfills. Furthermore, the list of e-waste for trading from the DTI Manual is outdated and lacks updates for the new, modern EEE collected. Additionally, there is a lack of available data on how these junk shops manage their e-waste and the residual waste generated in the recycling process.

In light of this situation, the researchers will engage with junkshop owners and workers in the municipality of Marilao, Bulacan, to study their inventory and process of e-waste management. The main objective is establishing an e-waste inventory to propose a management strategy for properly handling residual waste. Specifically, the study aims to (1) identify the list of WEEE being collected, (2) characterize the WEEE based on its value, (3) determine the components of WEEE that end up as residual waste, and (4) propose a management strategy for proper handling of WEEE residuals.

2. Material and Methods

2.1 Research Approach

The researchers utilized a mixed-method approach comprising interviews, observations, and survey questionnaires to gather comprehensive data. Survey questionnaires were distributed to five selected junkshops in Marilao, Bulacan, to accurately catalog the inventory of collected electronic waste (e-waste) and its associated residual waste. In addition to the surveys, interviews were conducted with either the owner or a worker representative from each junkshop to evaluate their management practices for residual waste. Complementing these methods, researchers also conducted observations of the facilities to gain insights into their operational processes and e-waste handling practices.

2.2 Sampling

The study employed a random sampling method to select five distinct junkshops across various barangays in Marilao, Bulacan, focusing on those that have been operational for over five years and actively collecting electronic waste (e-waste). This selection ensured the reliability of the data collected, as not all junkshops in the area engage in e-waste activities. Researchers used an online randomizer tool to facilitate the selection process within the municipality. The chosen junkshops were initially located in the barangays of Lambakin, Prenza 1, Prenza 2, Saog, and Lias.

Before the survey and interviews, researchers obtained consent from the junkshop operators, emphasizing voluntary participation and the right to decline to ensure their privacy. To protect the confidentiality of the respondents, the locations of the selected junkshops were anonymized and referred to as Site A, Site B, Site C, Site D, and Site E in the study. This anonymization was crucial in maintaining the participants' confidentiality in the research.

2.3 Research Instruments

The researchers created a survey questionnaire to inventory e-waste collected by junkshops, featuring checklists of electronic gadgets and appliances and questions on pricing, dismantling techniques, and residual waste management, aiming to assess respondents' knowledge and practices in e-waste handling. An interview guide was also prepared to ensure adequate information flow during on-site interviews. To protect participant privacy, consent forms and letters were distributed beforehand, allowing junkshops to choose whether to participate. Explicit consent was obtained for photographs and recordings, complying with Republic Act No. 10173 and the Data Privacy Act 2012. This ensures voluntary participation and maintains strict confidentiality of personal information and images collected.

2.4 Research Procedures

Since all five interviewed junkshops in Marilao, Bulacan, are privately owned, the researchers did not seek approval from the barangays. Instead, they distributed consent forms directly to participants for surveys, interviews, and observations, prioritizing confidentiality and data privacy in compliance with privacy standards.

2.4.1. Collection of E-Waste Inventory List

The researchers used a mixed-methodology approach, distributing survey questionnaires with checklists to junkshops in Marilao, Bulacan. This enabled precise data collection and the creation of an accurate inventory of electronic gadgets and appliances handled by these junkshops. The questionnaires covered e-waste disintegration methods and identified valuable e-waste types. The Department of Trade and Industry [24] states that trade-worthy e-waste includes CPUs, printers, copiers, and small devices such as microwaves and toasters. These were categorized using the European Commission's WEEE Directive 2012/19/EU [5] and ranked by value based on junkshop pricing. A separate list distinguished valuable items from typically discarded residual waste, clarifying the economic and environmental impacts of regional e-waste management.

2.4.2. Determining The Junk Shops' Processes for Disintegrating E-Waste (Baklas)

The researchers surveyed the electronic gadgets and appliances inventory, specifically examining electronic waste's disintegration processes. The study explored the term "baklas," commonly used by junkshop workers, to describe the disintegration of e-waste, discussing the tools and methods used, whether manual or automated. Additionally, the survey included questions designed to assess the use of harmful chemicals during the disintegration process, aiming to evaluate respondents' awareness of the potential adverse effects of these chemicals. This approach provides insights into the technical and safety aspects of e-waste handling practices in junkshops.

2.4.3. Determining The Junk Shops' Management of E-Wastes' Residual Waste

The survey questionnaire and interviews designed by the researchers' included questions about the methods used

by junkshops in Marilao, Bulacan to manage any accumulated residual waste. This approach aims to identify standard practices regarding the disposal of residual waste, examining whether junkshops sell, discard, or employ alternative methods. The investigation seeks to determine if junkshops see value in their residual waste or consider it mere disposable material destined for landfills alongside other solid waste. Respondents were given options on how they manage residual waste: (a) selling or giving invaluable parts to other collectors or junkshops, (b) not dismantling e-waste with invaluable parts and selling it as a whole, or (c) isolating invaluable e-waste parts and mixing them with solid waste for trash collectors.

The information collected is crucial for developing a management plan based on the responses regarding residual waste handling. This plan aims to enhance junkshops understanding of managing residual waste, recognizing its potential value, and preventing mixing such waste with solid waste. This plan allows junkshops to improve their waste management practices and promote sustainable e-waste handling.

Table 1. Categorized list of Electronic Equipment (European Commission's WEEE Directive 2012/19/EU)

Category	List of Electronic Equipment
Temperature Exchange Equipment	Refrigerators, freezers, equipment that automatically delivers cold products, air conditioning equipment, dehumidifying equipment, heat pumps, radiologists containing oil, and temperature exchange equipment use fluids other than water for temperature exchange.
Screens, monitors, and equipment containing screens having a surface greater than 100 cm2	Screens, Televisions, LCD photo frames, Monitors, Laptops, and Notebooks.
Lamps	Straight fluorescent lamps, Compact fluorescent lamps, fluorescent lamps, High-intensity discharge lamps - including pressure sodium lamps and metal halide lamps, Low-pressure sodium lamps, and LED.
Large Equipment	Washing machines, Clothes dryers, Dish washing machines, Cookers, Electric stoves, Electric hot plates, Luminaires, Equipment reproducing sound or images, Musical equipment (excluding pipe organs installed in churches), Appliances for knitting and weaving, Large computer mainframes, Large printing machines, Copying equipment, Large coin slot machines, Large medical devices, Large monitoring and control instruments, Large appliances which automatically deliver products and money, Photovoltaic panels.
Small Equipment	Vacuum cleaners, Carpet sweepers, Appliances for sewing, Luminaires, Microwaves, Ventilation equipment, Irons, Toasters, Electric knives, Electric kettles, Clocks and Watches, Electric shavers, Scales, Appliances for hair and body care, Calculators, Radio sets, Video cameras, Video recorders, Hi-fi equipment, Musical instruments, Equipment reproducing sound or images, Electrical and electronic toys, Sports equipment, Computers for biking, diving, running, rowing, etc., Smoke detectors, Heating regulators, Thermostats, Small Electrical and electronic tools, Small medical devices, Small Monitoring and control instruments, Small Appliances which automatically deliver products, Small equipment with integrated photovoltaic panels.
Small IT and telecommunication equipment (no external dimension more than 50 cm)	Mobile phones, GPS, Pocket calculators, Routers, Personal computers, Printers, Telephones.

2.5 Data Analysis

The researchers gathered data from survey questionnaires, which were then analyzed by calculating the mean to serve as the central tendency, thereby summarizing the entire dataset into a single value. The survey results were categorized into four main areas: an inventory list of e-waste collected, categorized by value; the processes employed by junkshops to dismantle e-waste and manage residual waste; and the list of residual wastes collected by junkshops within the respective barangays.

Following the analysis, the researchers created an inventory list detailing the electronic gadgets and appliances in the junkshops of Marilao, Bulacan, including item costs, residual waste lists, and dismantling methods. Alongside this, interview responses and observations underwent thematic analysis using six steps: familiarization, coding, generating themes, reviewing themes, defining themes, and writing up [25]. The inductive approach was selected to ensure that data analysis was free of preconceived notions or predetermined codes [26].

Interview audio recordings, transcribed with participant consent, formed the basis for coding, wherein significant text sections were highlighted and labeled with concise codes. These codes facilitated idea grouping into themes. Themes were generated by combining related codes, enabling the identification of data patterns [27]. Further, themes were reviewed for accuracy, followed by defining each to ensure clarity. Ultimately, the conclusions drawn from the thematic analysis were integrated into the results and discussion sections, offering insights derived from the identified codes and patterns [28].

3. Result and Discussion

3.1. Waste Electrical and Electronic Equipment Bought and Sold in Junk Shops and Their Respective Prices

Table 2 provides a comprehensive overview of the Waste Electrical and Electronic Equipment (WEEE) market within Marilao, Bulacan's junkshops, highlighting the average estimated prices for various electronic gadgets. Household appliances, including air conditioners, refrigerators, and freezers, are priced between ₱300 and ₱1000 for complete units, while incomplete units are sold at ₱10 to ₱12 per kilogram. CRT televisions are valued between ₱50 and ₱120 for complete units and ₱8 per kilogram for incomplete ones, while HD televisions fetch ₱50 for complete units and ₱2 per kilogram for incomplete units. Computer monitors and laptops are priced at ₱20 and ₱35, respectively, when complete, and electric fans range from ₱20 to ₱30 for complete units, with incomplete units sold at ₱8 per kilogram. Washing machines and dryers show a broader price range of ₱50 to ₱200 for complete units and ₱2 per kilogram for incomplete ones, while CPUs are estimated at ₱110 for complete units and ₱2 to ₱10 per kilogram for incomplete ones, depending on material composition. This summary underscores the economic value of complete and incomplete electronic units in the local WEEE market.

Certain Waste Electrical and Electronic Equipment (WEEE) items that lack prices for incomplete units suggest that junk shops either do not purchase them when incomplete or do not price them by weight. For instance, monitors, priced at ₱20, and motherboards, PC cards, and telecom cards, priced at ₱65, are only accepted when complete. Although rarely bought and sold in junk shops, laptops are accepted as complete units even if parts are missing; therefore, they are not priced per kilogram.

On the other hand, WEEE items that do not have prices for complete units are typically traded based solely on their weight. This category includes various electronics such as printer boards, medical-grade components, power and monitor boards, CPU parts (including cases, metal, and plastics), cellular phones, and wire cables like chargers and connectors. Specifically, printer boards, medical-grade components, and power and monitor boards are valued at ₱2.5 per kilogram. Cellular phones are priced between ₱50 and ₱300 per kilogram, depending on the device's build and material, while wire cables, including chargers and connectors, range from ₱6 to ₱12 per kilogram, depending on their metal content. This pricing approach reflects the different valuation methods junk shops employ for WEEE items based on their condition and material composition.

Table 2 shows that lamps are excluded from items accepted in junkshops due to their classification as hazardous waste [29]. Despite their potential for reuse, junkshops do not accept lamps, likely due to the risks associated with hazardous materials.

Table 2. List and Price Range of WEEE Bought and Sold in Junkshops (European Commission's WEEE Directive 2012/19/EU)

Category of WEEE	List of WEEE bought and sold in Marilao junkshops	Estimated average price in PHP (₱)	
		Complete Unit	Incomplete Unit
Temperature exchange equipment	Aircon, Refrigerator, Freezer	300 to 1000	10 to 12 per kg
Screens, monitors, and equipment containing screens having a surface greater than 100 cm2	CRT Television	50 to 120	8 per kg
	HD Television	50	2 per kg
	Monitor	20	-
	Laptop	35	-
Large equipment	Electric fans	20 to 30	8 per kg
	Washing machine/dryer	50 to 200	2 per kg
Small equipment	Printer boards/med-grade, power, and monitor board	-	2.5 per kg
	Microwave oven/convection oven	100	2 per kg
Small IT and telecommunication equipment (no external dimension more than 50 cm)	CPU	110	2 to 10 per kg
	Cellular Phones	-	50 to 300 per kg
	Wire cables (chargers, connectors)	-	6 to 12 per kg
	Motherboard/PC cards/Telecom Cards	65	-

3.2. Characterization of WEEE Based on Its Value Per Category

In comparing the categories and their economic values in Table 2, "Temperature Exchange Equipment" emerges as the most valuable among the WEEE categories in Marilao, Bulacan's junkshops. This category, which includes air conditioners, refrigerators, and freezers, commands prices ranging from ₱300 to ₱1000 for complete units. The substantial value of these items can be linked to their utility, demand, and the varying specifications and features contributing to their wide price range. Notably, even incomplete units within this category are priced higher per kilogram than others, underscoring their economic significance. As indicated by respondents, the preference of junk shops for this category reflects the consistent availability of recyclers willing to purchase these items, further highlighting their market importance.

Following this, the "Large Equipment" category, which includes electric fans and washing machines/dryers, holds moderate economic value. Complete units in this category are priced between ₱45 to ₱200, indicative of their utility in household settings. However, incomplete units are generally less valuable, with lower prices per kilogram than those in the temperature exchange and screens categories. Respondents noted that incomplete electric fans are seldom purchased unless the motor is intact, given the challenges of selling these to recyclers.

The "Screens, Monitors, and Equipment Containing Screens" category ranks next in economic value, comprising CRT televisions, HD televisions, monitors, and laptops. Prices for complete units in this category range from ₱20 to ₱120. Despite their more complex and costly recycling process, CRT televisions tend to fetch higher prices due to their valuable metal content, including leaded glass and copper. Conversely, HD televisions primarily composed of plastic and glass are less valuable unless they contain recoverable components like flat motherboards. Although less frequently traded, laptops retain considerable economic value as complete units, reflecting their significance in the electronics market.

The "Small Equipment" category, including printer boards, microwave ovens, and convection ovens, ranks lower in economic value. Despite their utility and higher initial cost, these items have lower average prices and demand in the secondhand market. Junk shops infrequently receive these complete or incomplete items for resale.

Finally, the "Small IT and Telecommunication Equipment" category is the least valuable, with items such as CPUs, cellular phones, wire cables, and motherboard/PC/telecom cards having relatively low average prices per kilogram. While these items are critical for recycling and resource recovery, their market value in junk shops is limited. Respondents highlighted that these items are rarely sold to junk shops, as they are typically directed to specialized markets, reflecting their niche demand outside the general e-waste stream.

3.3. The Processes of How the Junk Shops Dismantle Their E-Waste and Their Management of Residual Waste

Table 3, The data reveals varying practices among junk shops in Marilao regarding dismantling e-waste and managing residual waste. In Site A, it was found that the junk shop does dismantle e-waste manually. Dismantling the e-waste manually means they only use hand tools to dismantle the e-waste. However, they sell the residuals to other junk shops instead of managing the residual waste. This suggests a form of waste redistribution within the local junk shop network.

Table 3. Management of E-waste and Residual Waste per Junkshop

Junkshop	Dismantle E-Waste?	Method of Dismantling	Management of Residual Waste
Site A	Yes	Manual	Sell the residual waste to other junkshops
Site B	Yes	Manual	Mix residual waste with solid waste
Site C	Yes	Manual	Mix residual waste with solid waste
Site D	No		(Sells the e-waste as is)
Site E	No		(Sells the e-waste as is)

Similarly, the junk shops manually dismantle e-waste in Sites B and C. However, their approach to managing residual waste differs. Rather than selling it to other junk shops, they mix the residual and solid waste. This practice potentially contributes to the overall waste stream within the junkshops, which may have implications for waste management and environmental sustainability.

On the other hand, in Sites D and E, the junk shops do not dismantle e-waste. Instead, they opt to sell the e-waste as it is. This indicates a more straightforward approach to handling e-waste, with less involvement in processing or managing residual waste. Respondents from these junkshops stated that they do not dismantle the e-waste they buy, as most of it is already dismantled when purchased. The e-waste they receive is bought from *mga*

nangangalakal, also known as street waste traders. Even when they receive and buy complete units of WEEE, they prefer not to dismantle them, as most of the items are easily bought by recyclers when they are in a complete unit.

3.4. List of Residual Wastes Collected by Junk Shops from The Dismantling Process

Table 4, The list of residual waste with an estimated mass collected per month was given by the respondents that dismantle the WEEE they buy, and these respondents are from Sites A, B, and C. This list includes scrap/base/back plastics, screws, and styrofoam.

Table 4. List of Residual Waste per Junkshop and its Estimated Mass Collected per Month

Junkshop	List of Residual Waste	Estimated Mass
Site A	Base/scrap plastic	15 kg
	Screws	2 to 5 kg
	Glass	-
Site B	Styrofoam	25 kg
	Back plastics	10 kg
	Glass	-
Site C	Styrofoam	20 kg
	Back plastics	10 kg
	Glass	-

In Site A, residual wastes primarily consist of base/scrap plastics, with an estimated 15 kg collected monthly, and screws, ranging from 2 to 5 kg per month. These wastes are generated while dismantling electronic appliances like air conditioners and refrigerators. Notably, the junk shop at Site A is the only one that sells these residuals to other junk shops. According to the respondent, recycling facilities and junk shops are willing to purchase base/scrap plastics if they are well-segregated and the type of plastic is identified. Screws, although considered residual waste, can still be sold when accumulated.

In Site B, residual waste includes approximately 25 kg of styrofoam and 10 kg of back plastics collected monthly, resulting from dismantling appliances such as air conditioners, televisions, monitors, and laptops. Similarly, Site C collects around 20 kg of styrofoam and 10 kg of back plastics monthly. All three sites also list glass as residual waste, but no specific mass data is provided due to the immediate disposal of glass. The manual dismantling process, which uses hand tools, makes glass prone to shattering, reducing its value and making it difficult to recycle.

Interestingly, even junkshops that do not engage in dismantling activities acknowledge the presence of these residual wastes—base/back/scrap plastics, styrofoam, and glass—as integral components of the Waste Electrical and Electronic Equipment (WEEE) they receive. This finding suggests that regardless of the dismantling process, these materials are consistently part of the WEEE stream, highlighting the need for improved waste management strategies that address the challenges of handling and recycling such residuals.

Respondents collectively stated that the residual waste plastics are difficult to sell to recyclers. They mentioned that electric fan base plastic and television back plastic are hard to sell due to their materials. The motor is the most valuable part of an electric fan, especially those small and made of plastic. Television, high-definition in particular, the ones that are either LCD, OLED, or plasma, contain black plastics on the back part that is hard to sell to recyclers. Advanced recyclers of plastic use near-infrared (NIR) spectroscopy to treat plastics [30], [31]. However, black plastic does not reflect light, which means it cannot be detected or organized by the scanners employed in recycling machine facilities.

3.5. Management of Residual Waste of the Junk Shops

Proper processing and segregation of residual waste are integral to management. When the researchers visited the junk shops, it was observed that the junkshop in Site A has the most organized facility compared to the other junkshops visited. The junk shop has designated areas for processing, and all the dismantled items are segregated properly in their respective sacks. Figure 1, the base/scrap plastics are sorted based on color and type of plastic. While these plastics are deemed residual waste to other junkshops, Site A manages the residual waste by selling it to other junkshops and recycling facilities.

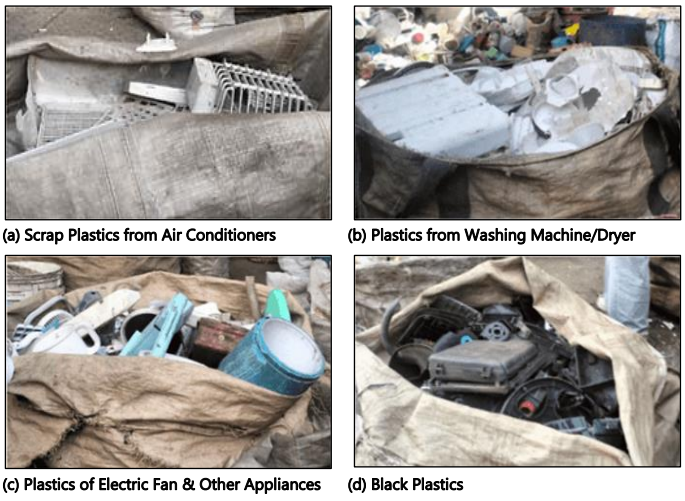
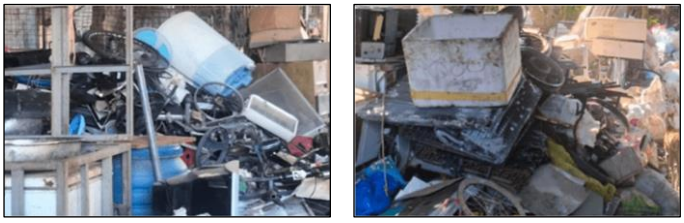


Figure 1. Residual Waste Plastics in Site A

On the other hand, the junkshops of Sites B and C claimed that it is difficult for their junk shop to sell these

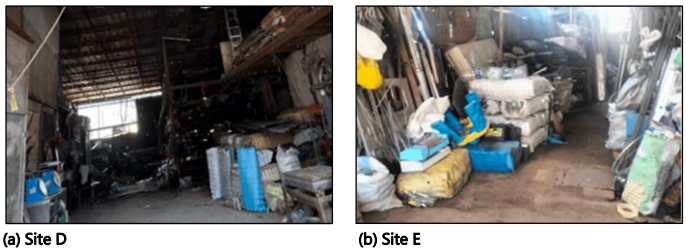
plastics. A common trend was observed upon the researchers' visit to both areas. In both locations, there appears to be a lack of thorough segregation of the waste being dismantled, classified as solid waste or e-waste. Figure 2 depicts open piles of residual waste alongside dismantled e-waste and solid waste materials destined for sale within these junk shops. Residual waste was mixed with solid waste only if deemed valuable for resale or recycling. However, certain residual waste from e-waste, such as glass, styrofoam parts, and scraps of plastics, are automatically considered invaluable. As a result, these items are typically disposed of and mixed in with solid waste management procedures for eventual collection and disposal by designated trash collectors.



(a) Site B (b) Site C

Figure 2. Open Pile of Scraps

In the junk shops at Sites D and E, no e-waste is visible inside the facilities. Figure 3 shows that these junk shops are well-organized, with specific areas for different functions. The only visible scraps are metal, plastic bottles, and cartons. Upon inquiry on their management of e-waste, the junkshops said they sell the e-waste as it is to other recycling facilities. Both junkshops sell and deliver e-waste immediately to prevent further deterioration. During the researchers' visit, the workers of the junkshops sold the e-waste they stored. Respondents mentioned that selling e-waste as is saves time since they handle various types of scrap, not just WEEE. However, this method leads to lower prices for e-waste, as items are valued based on their overall material and weight rather than specific components.



(a) Site D (b) Site E

Figure 3. The Environment of Junkshops

Comparing residual waste management, particularly e-waste, across visited junk shops reveals distinct approaches. Site A stands out for its efficient practices, featuring organized facilities and properly segregating dismantled items. In contrast, Sites C and D struggle to sell specific plastics, indicating inadequate waste segregation. On the other hand, Sites D and E junk shops adopt a different strategy, promptly selling e-waste to prevent deterioration but sacrificing detailed processing. While this approach saves time, it leads to lower prices, neglecting the potential value of specific components. These observations suggest a potential area for improvement in waste management practices within these junk shops, with a need for more comprehensive segregation strategies to optimize the recovery and recycling of valuable materials while minimizing environmental impact.

3.6. Management Strategies for Proper Handling of WEEE Residuals.

A comprehensive management strategy is vital for effectively handling Waste Electrical and Electronic Equipment (WEEE) residuals. Based on observations of current practices in dismantling and waste management among junkshops, the researchers propose several strategies to enhance the management of these residuals. First, developing a systematic approach to recycling and disposing of WEEE residuals is crucial. This approach should involve close collaboration with recycling companies and strict adherence to environmental regulations. Support from local governments is essential in creating sustainable management systems. By implementing policies and incentives that promote recycling and proper waste disposal, junkshops can be encouraged to establish collection points and receive financial assistance for recycling efforts. This collaboration and policy support would significantly enhance the effectiveness of waste management practices.

Second, there must be a strong emphasis on proper dismantling techniques to maximize the recovery of valuable materials from WEEE. Junkshops should utilize appropriate tools and methods to dismantle items effectively, ensuring that valuable components are recovered without causing environmental harm. Standardized dismantling procedures should be adopted to maintain consistency and safety across different sites, especially when using hand tools. Training workers in proper dismantling techniques is crucial for improving efficiency, minimizing the risk of injury, and preventing environmental contamination. By standardizing these procedures, junkshops can pre-calculate residual waste streams based on known dismantling processes, reducing uncertainty about the types and quantities of residuals produced and simplifying waste management.

Lastly, junkshops should implement robust waste segregation practices to manage residual waste streams effectively. This involves sorting materials by category,

such as plastics, metals, and glass, and ensuring that hazardous components are disposed of according to established environmental regulations. Junkshops should designate specific areas for sorting different types of waste, with practices like Site A's segregation of base and scrap plastics by color and type being implemented across all sites. Such practices facilitate better recycling outcomes and potentially increase the value of segregated materials. By improving waste segregation, junkshops can contribute to more efficient recycling processes, reducing environmental impact and enhancing the overall sustainability of WEEE management.

Recycling of electrical and electronic waste (WEEE) is becoming a profitable market due to the growing use of electronic devices and stricter regulations mandating environmentally responsible disposal [32]. This creates a steady supply of materials for recycling industries, attracting businesses and entrepreneurs to the sector.

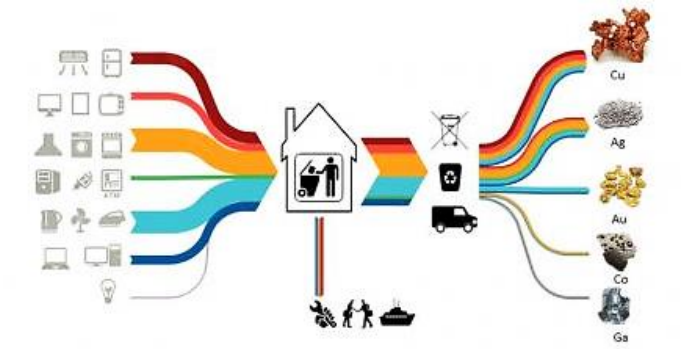


Figure 4. Electronic Waste Recycling [32].

Waste Electrical and Electronic Equipment (WEEE) residuals present a significant challenge in electronic waste management due to their hazardous and valuable materials, necessitating careful handling approaches. Research indicates that thermal and hydrometallurgical technologies hold potential for extracting valuable metals from WEEE residuals. However, challenges related to high costs and significant energy demands remain major barriers to widespread adoption [33]–[35]. Additionally, recycling technologies like pyrolysis have been developed to process mixed plastics from WEEE into new raw materials, demonstrating that technological innovation can reduce the volume of residuals that cannot be recycled [36]–[39]. This approach requires strong government policy support to ensure sustainable waste management and mitigate environmental impacts [40]–[44].

Optimization of recycling processes also plays a crucial role in reducing the amount of WEEE residuals and their environmental impact. Through life cycle analysis, optimized recycling processes have been shown to significantly decrease the quantity of residuals and mitigate adverse environmental effects [45]–[49]. Regarding recovering valuable metals, bioleaching methods utilizing microorganisms to dissolve heavy metals such as copper and gold from WEEE residuals offer a more environmentally friendly alternative than conventional methods that rely on toxic chemicals [50]. Furthermore, gasification technology is effective in converting mixed plastics into synthetic gas (syngas), which can be used as an alternative energy source while simultaneously reducing the volume of plastic residuals [41], [51], [52].

The management of WEEE residuals in developing countries is further complicated by inadequate infrastructure and regulatory frameworks. Studies suggest that public education, enhanced regulations, and investments in recycling technology are essential to address these challenges [53]–[55]. Additionally, the negative environmental and human health impacts of heavy metal residues and hazardous chemicals in WEEE underscore the importance of proper and safe management to protect communities [56]–[59]. This research underlines that while significant challenges exist, innovative technology- and policy-based solutions can effectively reduce the negative impacts of WEEE residuals on the environment and public health. However, further implementation is necessary to achieve sustainable management.

4. Conclusion

Managing Waste Electrical and Electronic Equipment (WEEE) remains a critical challenge as the increasing use of electrical and electronic equipment (EEE) leads to a corresponding rise in WEEE production. Junkshops play a pivotal role in the WEEE market by dismantling electronics to sell valuable parts. However, residual wastes that cannot be sold often end up in landfills without proper disposal or segregation. The study's inventory reveals that "temperature exchange equipment" holds the highest economic value, selling for ₱300 to ₱1000, making it a priority for buyers and sellers. In contrast, small IT and telecommunication equipment have the lowest economic value due to a distinct market focus. While many junkshops sell e-waste based on part value, not all dismantle the e-waste they receive. Those that do dismantle typically manage residuals by selling them to other collectors, selling the entire e-waste without dismantling, or mixing residual waste with solid waste. Common residuals include glass, styrofoam, and base plastics, often processed with basic hand tools.

To address these challenges, the study proposes three strategies for improving WEEE management: (1) partnering with local governments and recycling

companies to establish systematic disposal approaches, (2) emphasizing proper dismantling techniques to maximize material recovery, and (3) ensuring effective waste segregation practices for managing residual waste streams. These strategies aim to guide local governments in addressing the growing residual waste problem. Additionally, the researchers recommend further assessments by collaborating with local government units (LGUs) and Materials Recovery Facilities to investigate WEEE treatment, particularly for small IT and telecommunication equipment, and conducting surveys in junkshop hotspots across different municipalities, especially in the National Capital Region (NCR), to gather more comprehensive data on e-waste residuals management.

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