E-waste the Impending Epidemic: A Systematic Literature Review on the Challenges of E-waste Management

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Abstract

This dissertation examines the global e-waste management challenges. This topic is particularly important due to expanding digital technology adoption and subsequent e-waste generation. Due to this, there is a need for effective and globally coordinated e-waste management. The study is conducted through a systematic literature review process. This comprehensive methodology allows for the synthesis of relevant research on the topic of e-waste management challenges.

Key findings suggest a dichotomy in the e-waste narrative. While e-waste is a potential source of valuable recyclable materials and income for those in emerging economies, it simultaneously poses a significant environmental and health threat. The study also uncovers other significant issues contributing to the management challenges. These include a lack of accurate data reporting, minimal enforcement of regulations, and generally limited awareness of all aspects of e-waste issues. Additionally, the health and environmental repercussions of improper e-waste handling, particularly affecting marginalised workers who participate in the informal recycling sector out of necessity, are highlighted.

Future research is recommended in the area of integrating Extended Producer Responsibility and Circular Economy into a global e-waste management approach. Furthermore, research into developing a standardised reporting system for e-waste, particularly in countries with a large informal recycling sector, is also recommended.

This study underscores the urgency of addressing the e-waste issue and calls for a multi-stakeholder approach that is economically viable, environmentally sustainable, and socially equitable.

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Attestation of Authorship *"I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person (except where explicitly defined in the acknowledgements), nor material which to a substantial extent has been submitted for the award of any other degree or diploma of a university or other institution of higher learning"*

Signed:

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1 Introduction

People have grown more reliant than ever on modern technology. Digital devices have become intrinsic to our lifestyles. They shape everything from how we communicate and learn to how we entertain ourselves and conduct business. However, this incessant demand for digital innovation and the constant turnover of devices has led to a mounting issue, end-of-life electrical and electronic waste (e-waste) (Robinson, 2019). The growing e-waste problem prompts urgent exploration of the challenges that compromise the effectiveness of current e-waste management strategies.

1.1 Background

As the twenty-first century progresses, technological innovation continues to shape and refine our way of life. Although transformational and advantageous in many ways, this digital revolution has led to the global e-waste challenge. Rapid product cycles, consumer demand for the newest gadgets, and poor recycling and disposal practices generate unmanageable amounts of e-waste globally.

E-waste management challenges are complex and include the dangerous hazardous materials present in e-waste, the technological and financial practicality of formal recycling, public knowledge and awareness, and compliance with regulations and legislation. While current literature addresses global e-waste issues, it is essential to understand how these challenges affect e-waste management strategies. To achieve this, a systematic literature review was undertaken.

This systematic literature review explores the critical question:

> *What are the underlying challenges that compromise the effectiveness of current e-waste management strategies globally?*

The justification for employing a systematic literature review methodology centres on the need to comprehensively assess the existing body of knowledge, provide a synthesis of current

knowledge and identify gaps for further investigation. The e-waste challenge is global (Shittu et al., 2021) and this review attempts to provide a diverse viewpoint that recognises this global character ~~of e-waste~~ while acknowledging the need for region-specific solutions. Policymakers and the general public will gain from the findings of this systematic literature review as they all have a stake in finding solutions to this growing problem. With the threat of an impending e-waste epidemic, a comprehensive examination of the challenges of e-waste management in the current literature is necessary.

1.2 Dissertation Outline

This dissertation research project comprises six main chapters. These include an introduction, literature review, methodology, findings, discussion and conclusion.

Chapter One provides a broad overview and background to the research and introduces the problem of e-waste management. Moreover, it defines the aim of the research and presents the research question.

Chapter Two provides a theoretical background by exploring existing scholarly literature relevant to e-waste, including a definition of e-waste. This chapter touches on important aspects such as global regulations and legislation, generation and recycling rates, and challenges facing e-waste management.

Chapter Three outlines the methodology adopted for data collection. This chapter provides a detailed account of the Scientific Procedures and Rationales for Systematic Literature Reviews (SPAR-4-SLR) approach implemented in this study. It discusses the process involved in selecting databases, keywords, inclusion and exclusion criteria and compatibility of articles with the research aim. It also provides information on how thematic analysis was used to interpret the data.

Chapter Four presents the findings of the systematic literature review from the data. This chapter synthesises and critically analyses the literature from the selected studies. Through thematic analysis, four themes were explored surrounding challenges in e-waste management. These themes include ‘informal sector in emerging economies’, ‘policy and legislative frameworks’, ‘limited awareness’ and ‘health and environmental impacts’.

Chapter Five, the Discussion chapter, further elaborates the findings. Then finally, the dissertation concludes with Chapter Six, the Conclusion chapter. This chapter discusses imitations and areas for future research, and the dissertation is concluded.

2 Literature Review

As the world becomes more reliant on digital technology and industries adopt automation, the amount of e-waste generated continues to increase at an alarming rate across the globe (Shittu et al., 2021). This is exacerbated by some equipment's relatively short life span due to the frequent release of upgraded features and capabilities. E-waste refers to waste from end-of-life electronic and electrical equipment (Perkins et al., 2014). Defining electrical and electronic equipment (otherwise known as EEE) with a greater emphasis on technical details is provided by the European Union (2012) as

> "equipment which is dependent on electrical currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields and designed for use with a voltage rating not exceeding 1000 Volts for alternating current (AC) and 1500 Volts for direct current" (p. 43).

When no longer useful or wanted by their users, these devices become waste of electrical and electronic equipment (WEEE). The terms e-waste and WEEE will be used interchangeably throughout this review.

When taking a more granular look at the majority of EEE, it comprises a combination of organic and inorganic components, which include dangerous (sometimes hazardous) substances such as lead, cadmium, mercury, and brominated flame retardants alongside the recyclable, valuable and rare materials such as copper, gold, platinum, and rare earth elements, which can be repurposed back into the production of new products at a lower cost than that of the primary output (Bakhiyi et al., 2018; Ikhlayel, 2017). The dichotomy EEE presents when it becomes WEEE, where there is potential for valuable material recovery that simultaneously causes environmental and health hazards, calls for an integrated approach to e-waste management. The complexity continues when e-waste is seen in the context of globalisation, making it easier for e-waste to cross international borders. The transboundary movement of e-waste has led to the least equipped nations shouldering the burden of hazardous yet valuable waste. International agreements and guidelines seek to prevent the dumping of e-waste and encourage responsible

and sustainable e-waste management practices. From a neo-institutional perspective, these norms and standards can be viewed as coercive pressures exerted on organisations and countries to drive them towards more responsible e-waste management practices (Di Maggio & Powell, 1983). However, as the varying levels of compliance to these standards demonstrate, the effectiveness of the coercive pressures depends on different factors. These include economic conditions, existing regulatory frameworks, and the perceived benefits of compliance or non-compliance.

The Basel Convention's environmental treaty on the Control of Transboundary Movements of Hazardous Wastes and their Disposal in 1989 was brought about due to the growing issue of hazardous waste ending up in landfill, burned, or exported to emerging economies. It was designed to minimise hazardous waste movement across international borders, including e-waste. In particular, it intended to stop hazardous waste from ending up in emerging economies where the infrastructure and knowledge to dispose of it safely was limited, creating a risk to the environment (Khan, 2016).

By 1993, engagement on the Basel Protocol on Liability and Compensation had begun. However, this would not come into effect until 2003. This protocol was initiated by emerging economies' inability to cope with illegal dumping and accidental spills. It ensures that the responsibility for any damage caused by the transboundary movement of hazardous waste lies with those who cause the damage, while compensation is paid to those affected (Basel Convention, 2011).

The Basel Ban Amendment, adopted in 1995, aimed to prohibit the export of hazardous waste from advanced economies to emerging economies, including for recycling, to protect the environment and the health of those in emerging economies. Lower costs and weaker regulations in emerging economies mean they are a desired option for e-waste exporting, regardless of the environmental and health damage it creates for local communities (Basel Convention, 2011).

Though the EU and some emerging economies have ratified the amendment, Australia, the United States, Canada, and Japan have yet to agree on it, citing negative economic impacts and the hindering of a global recycling market as reasons why. The Ban Amendment came into force of law in 2019 when it reached the requisite number of countries. Regardless of being ratified or not, the Ban Amendment states that an advanced economic country cannot export hazardous waste to an emerging economic country that has ratified the ban (IPEN, 2020). Nevertheless, the potential financial gains from importing and exporting e-waste outweigh the associated negative effects for some.

The percentage of e-waste recycling worldwide increased slightly from 17% in 2014 to 17.4% in 2017. However, this suggests that efforts to address e-waste have yet to keep pace with the rapid e-waste generation rate (Van Yken et al., 2021). More than 53M tonnes of e-waste were reportedly created globally in 2019, an increase of 9.2M from five years previous. The Global E-Waste Monitor predicts this to exceed 74.7M tonnes by 2030 (Ghimire & Ariya, 2020). Oceania has the highest EEE ownership per person at 19.7kg, surpassing Europe and the Americas; conversely, at the lower end, Asia sits at 9.5kg and Africa at 2.5kg (Forti et al., 2020). In addition, Oceania ranks second highest in terms of e-waste generated per capita. Despite their high EEE ownership and e-waste generation figures, Oceania has the second lowest e-waste collection rates globally (Forti et al., 2020). The difference between generation and collection rates in advanced and emerging economies underscores the need for comprehensive and effective management strategies.

E-waste management of e-waste presents various challenges that must be overcome to achieve sustainable e-waste management. Shittu et al. (2021) observed that a significant obstacle was a lack of accurate data reporting on WEEE generation and disposal. The absence of a standardised approach to classify and report WEEE has resulted in inconsistent data, making it difficult to draw meaningful comparisons. This issue is more significant in countries with a high number of informal recycling sectors, where the estimation or reporting of data may be inaccurate or underestimated (Shittu et al., 2021). Another challenge highlighted by Shittu et

al. (2021) centred around the contribution device obsolescence has to e-waste generation. This can occur due to technical or economic reasons. Mobile phones and laptops make up a considerable amount of e-waste due to their short lifespan and the desire of consumers to have the latest technology (Robinson, 2009).

Alongside unclear data and device obsolescence, Arya and Kumar (2020) pointed out that a lack of technical expertise is a significant challenge for emerging economies. The predominantly underprivileged workforce of the informal sector is often involved in the unprofessional treatment of e-waste, which is frequently dumped in municipal buns. This mixture of e-waste and improper handling has led to environmental and health hazards for those employees and the surrounding areas. To provide a clearer understanding of these processes Figure 1 illustrates the typical journey of e-waste through the informal sector.

Figure 1: E-waste flow through the informal sector (figure created by author)

Managing the high amount of e-waste produced is also hindered by a lack of community engagement, whereby people are unaware of how and what can be recycled or how their

disposal choices affect the e-waste problem and the environment (Rautela et al., 2021). A study on the recycling habits of households found a lack of knowledge about the environmental impact of storing e-waste and where the recycling and disposal responsibility should lie (Blake et al., 2019). Respondents remained split on whether the producer or consumer was to blame for the e-waste generation - the consumer for excessive purchasing behaviour or the producer for planned obsolescence in their products.

Extended Producer Responsibility (EPR) was first conceptualised by Swedish economist Thomas Lindqvist in 2000. He suggested that the physical and financial responsibility of disposal of end-of-life goods and their packaging should fall with the producer's, rather than the municipalities and consumers (Sikaria, 2023). This can be facilitated via a take-back scheme. This can be seen as a type of normative pressure, outlined in neo-institutional theory as the social expectations and norms that influence an organisation's behaviour (Di Maggio & Powell, 1983). A take-back scheme thus creates an opportunity for the producer to minimise the environmental impact of their products. The effectiveness of this depends on whether producers internalise these expectations and whether the consumers reinforce the norms. This approach could also incentivise producers to develop longer-lasting products that are more easily disassembled and recycled when they reach end-of-life, as they are now held responsible for the product's disposal (Pouikli, 2020; Leclerc & Badami, 2020).

EPR is a tool which promotes the implementation of the Circular Economy (CE). CE has been gaining traction for the last number of years. The primary objective of the CE framework centres around promoting the continued use of materials in a cyclical fashion where waste becomes raw materials lessening the impact on the environment and boosting the economy. The aim is to create a closed-loop system where products, materials and resources are recirculated through reuse, refurbishment, remanufacturing, and recycling practices (Moraga et al., 2019; Isernia et al., 2019). Within the institutional environment, there is an expectation for sustainable and responsible behaviour throughout a product's lifecycle. In order for these concepts to work, regulatory frameworks must reward sustainable practices and discourage the contrary. The

success of EPR and CE in facilitating successful e-waste management in some advanced countries shows the influence of coercive pressures in shaping behaviours in institutional environments.

In conclusion, the growing global problem of e-waste production, spurred by the acceleration of digital technology adoption and technological upgrades, presents a complex issue. E-waste is both a valuable source of recyclable materials and a potential environmental and health hazard, intensifying the need for effective strategies to manage it. While international agreements and initiatives such as the Basel Convention have sought to regulate the transboundary movement of hazardous waste, their effectiveness is constrained by a lack of universal ratification and the economic benefit of e-waste import and export.

Existing e-waste recycling efforts have proven insufficient, with recycling rates lagging behind e-waste generation rates. Key obstacles to sustainable e-waste management include a lack of accurate data, technical expertise deficits in emerging economies, unclear regulations, and insufficient community engagement. These challenges are further complicated by the high rate of EEE ownership and the discrepancy in e-waste collection rates between advanced and emerging economies. The Extended Producer Responsibility and Circular Economy concepts present promising solutions, however, more needs to be done to integrate these strategies into a global approach to e-waste management so as to ensure that the digital revolution does not result in an environmental disaster.

3 Methodology

This study is a systematic literature review on the underlying challenges that compromise the global effectiveness of current e-waste management strategies. There are many approaches to conducting a literature review including traditional, narrative review, meta-analysis, and meta-synthesis (Cronin et al., 2008). A systematic literature review is a comprehensive method of synthesising research using a structured and transparent approach that identifies and evaluates all the relevant research on a specified topic (Siddaway, 2014). It is different to the traditional literature review approach where selection bias is more likely to occur due to the author's preferential inclusion of studies that back up their research findings (Nightingale, 2009). The steps involved in the systematic literature review process are outlined next.

3.1 Steps Involved in Systematic Literature Review

The methodology applied for this systematic literature review is based on the framework "SPAR-4-SLR", which stands for Scientific Procedures and Rationales for Systematic Literature Reviews (Paul et al., 2021). This guide contains three stages and six sub-stages to direct the development of the review.

The three main stages of the framework are assembling, arranging, and assessing, with each stage containing two sub-stages. Firstly, assembling refers to the initial data identification and data acquisition through databases. Identification involves deciding on a research topic and guiding research questions, the scope of the review, and the source type of data to be used in the review (e.g., peer-reviewed journal articles). The assembling stage also includes acquisition which involves determining what keywords most accurately reflect the research objective and which research databases are most suitable.

The arranging step comprises organisation and purification. Organisation involves drawing out essential information from each article and grouping them to filter them for relevance easily. Purification facilitates this filtering process where inclusion and exclusion criteria are applied to

the results. This ensures that only the most relevant results make it to the assessing stage. This assessing stage involves evaluation and reporting. The evaluation stage posits which analysis method will be applied for this literature review: a thematic analysis. This step will also highlight any gaps and areas for future research. Lastly, the reporting section covers any limitations and sources of support that were present (Paul et al., 2021).

3.1.1 Assembling

To begin the data selection process, three databases were identified as suitable for an extensive search, ensuring a broad spectrum of literature was captured. The databases selected were EBSCO, Emerald Insights, and Scopus.

EBSCO was used as it has an extensive range of good quality full-text content available and is a reliable database for researchers (EBSCO, 2023). Emerald Insights, managed by Emerald Publishing, is known for its solid subject coverage in business and management, making it an appropriate database for this research (Emerald Publishing, 2023). Finally, Scopus offers more global content and is customisable to search for keywords based on title, abstract, and keyword, which makes it easier for the user to find relevant articles.

While searching the three databases, the Boolean operator "AND" and the connector "OR" were used to pick up multiple variations of results. The keywords used were (electrical waste OR electronic waste OR e-waste) AND (challenges OR barriers) AND (management). This initial search generated 1,071 papers in total. The results were narrowed down to peer-reviewed journal articles only, duplicates were removed, and a subject/keyword search was carried out to ensure the article was relevant to the research question.

When filtering the search results, several variables were considered to only include the most relevant and reliable results. These included the type of source, language, time frame, and keyword or subject relevance to the literature review.

3.1.2 Arranging

The three databases yielded 1,071 search results in total. The search was narrowed to peer-reviewed journal articles only, as publishing in a journal requires intense scrutiny and vetting, meaning the researcher can be confident in the quality of the research (Paul et al., 2021). While the most credible source, journals stay current on the latest research in a particular field. Applying the peer-reviewed journal article criteria lowered the results to 732, with conference papers, books and other search results excluded at this stage. The justification for having only English journals is that the researcher's first language is English, meaning the article can be fully understood and analysed. Ten of the results were non-English journals, meaning 722 results remained. No timeframe was set for this research so as not to exclude any research that may be relevant, meaning publish date will not influence whether they were included or excluded, though most results came from the last ten years. Following the keyword and subject relevance to the literature review search, 253 eligible articles were brought through for manual title and abstract screening. At this stage, a manual review of the title and abstract further narrowed down the results based on the article's relevance to the systematic literature review. Ten duplicates were removed, as well as a further 153 at this stage, which left 90 articles remaining. The remaining articles needed to be centred around the challenges facing e-waste management. Further screening of these articles' abstracts, introduction, and findings sections left 26 articles for full-text review. Figure 2 illustrates the final articles by publishing year, showing the majority have been published in the last 10 years.

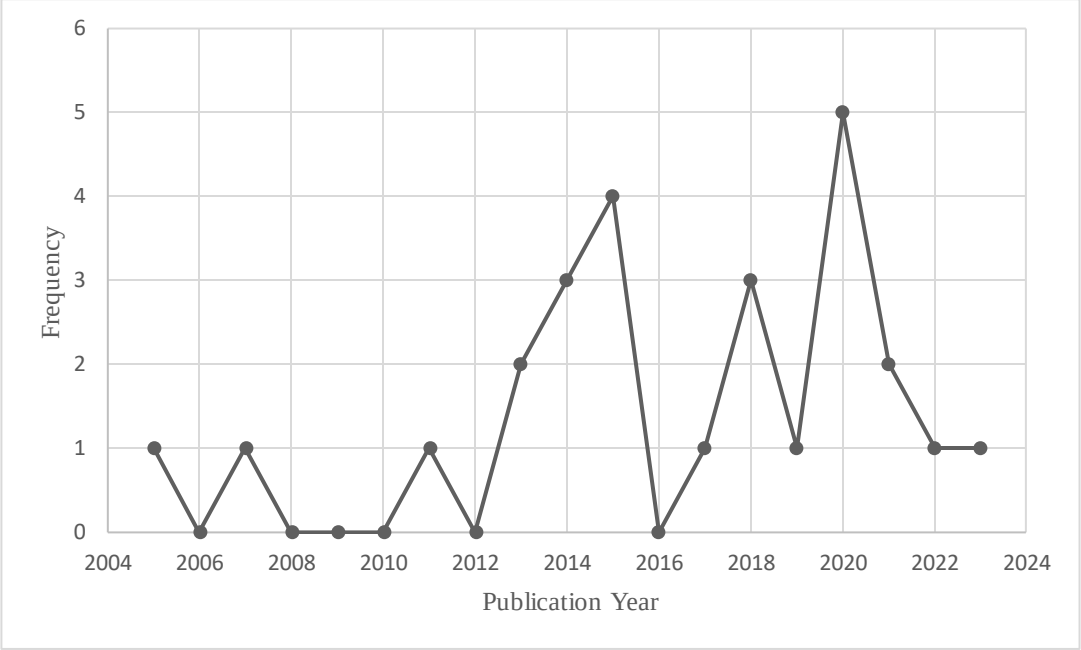

Figure 2: Publishing year of final articles

3.1.3 Assessing

The review of the literature involved thematic analysis of the remaining full-text articles. As a novice researcher, I found following the six-step method by Braun & Clarke (2006) an appropriate way to analyse the articles in order to answer the research question. The process involved familiarising the articles by reading them multiple times and making notes on initial codes that stood out. I found it most useful to keep track of this information in an Excel spreadsheet. Once this was completed, the codes were sorted into sub-themes and finally grouped into four main themes. A more detailed summary of the open codes is included in Appendix 8.1. Each theme was then refined and given an appropriate name to reflect the data it represented. The last step involved producing the findings through weaving and synthesising the studies in relation to the research question. This process was done iteratively rather than in a linear fashion as the themes evolved and overlapped with one another.

Figure 3 outlines the SPAR-4-SLR framework and how the three A's were applied to this literature review. By following the SPAR-4-SLR framework and applying thematic analysis, this study has provided a review of the current knowledge concerning the underlying challenges that compromise the effectiveness of current e-waste management strategies globally.

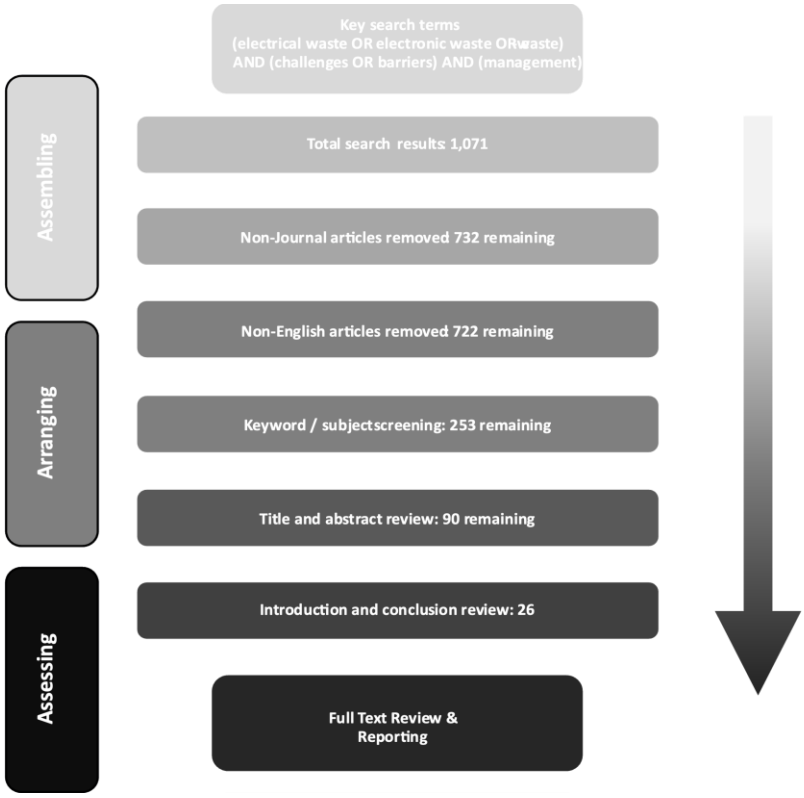

Figure 3: SPAR-4-SLR Process

	Scopus	EBSCO	Emerald
Total Articles	521	474	76
Journal Article only	272	386	67
English only	272	383	67
Keyword screening	115	71	35
Duplicates removed		*8*	
Title and abstract review	47	25	10
Full text review	**14**	**9**	**3**

Table 1: Search results table

4 Findings

The following sections will delve into the findings of the systematic literature review and offer an analysis that answers the research question "What are the underlying challenges that compromise the effectiveness of current e-waste management strategies globally?". These findings were derived from the thematic analysis process outlined in the methodology section and are designed to provide a synthesised view of the current literature.

4.1 Themes

The following sections break down each theme based on the insights gathered from the systematic literature review. The review examined a wide range of studies to explore underlying challenges that compromise the effectiveness of current e-waste management. The identified themes include the 'informal sector in emerging economies', 'policy and legislative frameworks', 'limited awareness' and 'health and environmental impacts'. These themes emerged as significant factors influencing effective e-waste management. This review provides a comprehensive overview of the current knowledge and understanding of these themes through analysing the literature. The themes are presented below in Table 1; the following section describes each theme in depth.

Themes	Sub-themes
Informal Sector in Emerging Economies	Economic and financial situation Insufficient infrastructure Misdeclaration of goods Trans-boundary movement of e-waste
Policy and Legislative Frameworks	Regulations Legislation Standardisation Extended Producer Responsibility
Limited Awareness	Education Knowledge Lack of data Unreliable data
Health and Environmental Implications	Informal recycling activity Priorities Contamination routes

Table 2: List of themes and sub-themes of e-waste management challenges

4.1.1 Theme 1: Informal Sector in Emerging Economies

Multiple studies presented a comprehensive understanding of the global informal e-waste sector's challenges and implications. Although the studies focus on different regions – China (Wang et al., 2017), Ghana (Okwu et al., 2022), Malaysia (Shumon et al., 2014), and Nigeria (Gollakota et al., 2020) - they expose common themes related to e-waste management that indicate systemic issues across emerging economies.

The concept of the informal economy includes a wide range of unregulated economic activities. These range from street vending and scrap collecting to small-scale manufacturing and informal e-waste recycling. This sector offers opportunities to create an income when formal routes are inaccessible, though not officially recognised or governed by regulations. Within a larger context, informal e-waste management has evolved as an example of the informal economy's operations and one that is more profitable among the other informal activities. Alongside the economic benefits of the informal sector, key barriers in formalising e-waste collection systems include a lack of effective regulation and the convenience of disposal through selling e-waste to peddlers - indicating the need for a behavioural shift among consumers (Wang et al., 2017; Okwu et al., 2022). Similarly, the expense incurred by formal recyclers to treat and collect WEEE often exceeds the income gained from valuable material recovery, giving the informal sector an advantage (Shumon et al. 2014).

The challenges within Nigeria's informal e-waste sector are connected to the dynamics of the larger informal economy. They include the misdeclaration of e-waste at entry points, the inability to differentiate WEEE from near-end-of-life electronic equipment, and the lack of standardised recycling systems (Okwu et al., 2022). Approximately 25-75% of EEE imports to Nigeria were labelled as second-hand goods but on inspection rendered as unusable junk (Osibanjo, 2007). While important, the practical concerns are just the beginning, as a lack of viable formal employment, poverty, and Nigeria's economic conditions push many towards the informal sector as a way to survive. Exacerbating this, the absence of appropriate infrastructure and formal collection points increases the likelihood of people using informal channels (Chen et

al., 2010), with the informal sector often able to provide better prices and a more convenient experience (Bakhiyi et al., 2021).

As previously mentioned, the reasons for individuals' involvement in informal e-waste recycling in Nigeria are often driven by socio-economic factors. These include the need for employment and tax-free income (Okwu et al., 2022). This is not confined to Nigeria with a significant number of people employed in the informal sector and contributing to the GDP in sub-Saharan Africa (Maphosa et al., 2020). The informal sector is facilitated by the role of systemic corruption and greed from importers, with instances of officials accepting bribes to turn a blind eye to illegal hazardous practices (Rajesh Ejiogu, 2013). However, some informal recyclers demonstrated a greater willingness to comply with government guidelines if they were compensated for their work in gathering e-waste items (Okwu et al., 2022). Adding to the challenges facing those working in the informal e-waste industry, it is worth noting that even when machinery and technology are available to assist in the dismantling of e-waste, those working can lack the skills and training to operate these tools. As a result, they resort to manual methods for processing e-waste (Gollakota et al., 2020).

More critically, the socio-economic condition of deprivation pushes marginalised social groups who have less economic security into informal e-waste management activities. Their vulnerable position of needing to work no matter the conditions often attributes to the health and safety barriers at work, leading to an increased risk of occupational illness and injury (Bakhiyi et al., 2018). Health hazards are a major concern, particularly from exposure to harmful chemicals from household appliances. Informal recycling is not only detrimental to human health but also contributes to the deterioration of the environment around the informal sites. The consensus is that informal e-waste recycling leads to both health risks and environmental harm (Qu et al., 2013; Chen et al. 2010).

In summary, the informal sector's dominance in e-waste management is evident across the studies, and its challenges are diverse and interconnected - these range from regulatory

inefficiencies and consumer behaviours to health and environmental implications. The sector's informal nature, coupled with barriers to formalisation, makes addressing these challenges a complicated task. There is a strong agreement among the studies on the importance of encouraging cooperation between the formal and informal sectors to ensure sustainable e-waste management.

4.1.2 Theme 2: Policy and Legislative Frameworks

Analysis of the studies conducted in Europe (Anderson, 2021), Pakistan (Iqbal et al., 2015), Malaysia (Shumon et al., 2014), Australia (Diaz et al., 2019), and China (Lu et al., 2018; Zhang et al., 2015) sheds light on the complex issues surrounding the regulation of e-waste management globally. The theme of policy and legislative frameworks helps understand the challenges of e-waste management in both advanced and emerging economies. These issues include inconsistent and unclear regulatory frameworks and the need for stakeholder education surrounding them, difficulty with enforcement, and a lack of international harmonisation.

There is considerable variation and inconsistency in e-waste regulations, even within unified frameworks such as the European Union's WEEE directive (Anderson 2021). Anderson (2021) emphasised that despite a shared framework, the implementation diverged considerably from country to country. This has caused confusion and inefficiencies for manufacturers and stakeholders of countries under the directive who are required to report on their e-waste. The discrepancy was further exemplified by the changes in the WEEE directive's categories of e-waste, most recently from ten categories to six, illustrating the regulatory complexity that manufacturers face in different jurisdictions. In response to this confusion manufacturers and importers who aim to err on the side of caution often over-reported their activities to ensure they fulfil their Extended Producer Responsibility (EPR) requirements. However, this inaccurate data skews the extent of the e-waste problem, creating further complications when implementing management strategies (Anderson, 2021).

There is particular disparity between the EU and China (Lu et al., 2018) concerning the concept of reuse in WEEE management. While the EU directive has its complexities due to inconsistent application across member states, it does incorporate a broader strategy for dealing with e-waste, encompassing waste minimisation, reuse, and recycling. In contrast, China's approach remains primarily focused on recycling, which neglects the potential benefits of reuse and refurbishment (Lu et al., 2018). This inconsistency underscores the need for harmonisation of regulations and legislation, a key concept noticed across many studies. Anderson's (2021) research highlighted the potential benefits of harmonising the WEEE directive with Circular Economy (CE) policies across the EU, with this alignment simplifying reporting and environmental fee calculations.

The lack of uniform regulations poses a significant challenge in e-waste management practices. The absence of standardisation can lead to questionable practices, as seen in Australia (Diaz et al., 2019). The economic motivations behind Australia's outsourcing of e-waste recycling to countries with lower labour costs often compromise environmental standards due to different regulatory landscapes. Diaz et al (2019) therefore, advocated for better monitoring tools and regulations, particularly for transboundary movement. This resonates with Anderson's (2021) call for harmonisation but highlights the need at a global scale to ensure both economic and environmental sustainability.

While legislation is a critical part of e-waste management, studies from Pakistan (Iqbal et al., 2015) Malaysia (Shumon et al., 2014) and China (Zhang et al., 2015) emphasise the limitations and challenges of enforcement. These studies point to the prevalence of informal recycling and the ineffectiveness of the current laws in addressing this sector. While it is agreed that special laws to regulate and formalise e-waste recycling are critical, the enforcement of such laws is a major barrier to effective e-waste management (Iqbal et al., 2015; Shumon et al., 2014). A well-defined recycling target and enhanced supervision within a regulatory context have been suggested as a solution (Zhang et al., 2015).

The reviewed studies underscore the critical role of stakeholder awareness concerning their legislative requirements. Anderson's (2021) study accentuates the difficulties manufacturers experience in comprehending and meeting their obligations under EPR within the scope of the WEEE directive. It emphasises the crucial need for regulatory frameworks to be transparent and easily understandable. Similarly, the research conducted in Pakistan (Iqbal et al., 2015) and China (Zhang et al., 2015) underscores the importance of establishing, enforcing, and effectively communicating clear regulations and standards. It becomes evident that merely establishing policies is insufficient; the emphasis must also be on creating understanding for those required to abide by them.

4.1.3 Theme 3: Limited Awareness

The theme of limited awareness, particularly concerning the hazardous nature of e-waste and insufficient data and reporting exacerbating the knowledge gap, has emerged as a significant theme. This theme exposes the challenge at the very core of addressing e-waste issues effectively - that a lack of knowledge and understanding and incorrect information subsequently affects behaviour.

Arya & Kumar's (2020) review of e-waste challenges in India reported a knowledge gap within the public sphere and governing bodies. They held little information regarding the volume of WEEE being produced, referred to as WEEE generation rates, which created difficulties from the outset in tackling the problem. Similarly, Kwatra et al. (2014) public awareness study in Delhi delved into how middle-class people from varied educational and professional backgrounds perceive e-waste. Intriguingly, despite ongoing local and national awareness campaigns, only 44% could adequately define e-waste. This signifies a profound lack of awareness among the public that potentially underpins the growing e-waste problem. Furthermore, a staggering 90% were oblivious to any e-waste recycling activities in Delhi. Despite the enormity of the problem, only 4% (comprising only environmental engineers) grasped the full extent of the e-waste issue. An additional layer to this limited awareness is the 72% ignorant about the illegal importation of e-waste into India. This study demonstrates that

awareness is not a binary aspect - it has dimensions that reveal the depth of understanding about e-waste. It is not simply about knowing or not knowing, there are different layers of understanding. While some may know that e-waste is harmful, they may not know why or how to dispose of it properly. Though they may be aware of some regulations, it might not be clear how that relates to them specifically. Nevertheless, optimistically, when briefed about the associated problems, 88% of the participants recognised the potential societal harm if e-waste was not correctly recycled (Kwatra et al., 2014).

Exploration of the e-waste recycling industry in Sri Lanka underscored the effects of limited awareness. Sri Lankan households were found to be unknowingly hoarding potentially hazardous electronic items bringing a critical insight into consumer behaviour (Gunarathne et al. 2020). Similarly, in Liverpool, UK, 86% of people confessed to hoarding old mobile phones without understanding the potential harm these discarded devices could cause (Speake & Yangke, 2015). This shows that awareness challenges and hoarding tendencies are not limited to emerging economies - though differences in the types of items stored were noticed. Those in emerging economies were more likely to store larger appliances such as refrigerators whereas those in advanced economies were likelier to store smaller items out of sight, such as mobile phones, in drawers. As mobile phones are an item that is frequently upgraded in advanced economies it was surprising that 61.2% of participants were oblivious to mobile take-back services and were not made aware of them when purchasing new devices. Khetriwal et al. (2011) study of European lessons learnt shed some light on this negligence proposing that retailers might be inadequately informed about take-back schemes, primarily if they are recently implemented. This suggests a missed opportunity to educate consumers about these vital services at the point of sale. Comparatively in Switzerland, awareness alone was shown as insufficient to encourage pro-recycling behaviour, with interviewees working in the recycling sector admitting to storing old mobile phones themselves (Duygan, 2015). This may be down to the sheer size of mobile phones and the ease at which they can be stored. This reiterates that awareness is not a binary aspect, with even those holding a significant amount of knowledge not grasping the full extent of their actions.

While knowing about the intricate issues of e-waste is paramount, reliable data is critical for understating the full extent of the e-waste problem. A lack of data makes it impossible to garner a holistic view of the situation and make informed decisions when tackling the problem (Diedler et al., 2018). Similarly, the limited availability of information prevents the development of a cohesive management system (Arya & Kumar, 2020). Accurate data on factors such as e-waste generation rates, what types of electronic items are most discarded, and the common methods of disposal would help in the planning and implementation of effective strategies for e-waste management.

Another layer to this global issue is the realisation that perhaps those working in the informal sector bear the main burden of these knowledge gaps (Okwu et al., 2022). Alarming levels of unawareness about the potential hazards of informal e-waste recycling (72%) were found, which is similar to the unawareness levels of the hazardous nature of e-waste in general (Kwatra et al., 2020; Speake & Yangke, 2015). A disturbing percentage of workers in the informal sector misperceived e-waste management as merely throwing WEEE into an open dump or burning it. A lack of education and understanding of the importance of Personal Protective Equipment (PPE) was also found (Okwu et al., 2022).

In summary, across geographical contexts, there is a clear trend towards the need for more knowledge and awareness about proper e-waste disposal, the dangers of hoarding electronic items, and the importance of accurate data and recycling initiatives. As these findings have been consistently observed, it underscores the need for enhanced and targeted awareness campaigns at both a local and global level to encourage behavioural change and improve e-waste management.

4.1.4 Theme 4: Health and Environmental Impacts

The theme of health and environmental impacts of e-waste links in many ways to the previous themes. The effects of improper e-waste management, often present in the informal sector, directly contributes to severe health conditions, environmental disturbances, and the

contamination of natural resources like water, air, and soil. This causes immediate and long-term health risks and environmental issues.

Health and environmental concerns associated with e-waste are worsened by the lack of proper storage, transport, and treatment facilities present in the informal sector. The continuous exposure to humidity and dust through the e-waste's lifecycle intensifies these issues (Gunarathne et al., 2020). Emphasise has been given to the role of unregulated e-recycling practices in exacerbating these risks. Multiple exposure routes have been shown to lead to high doses of contaminants, particularly among children (Bakhiya et al., 2018). Particularly when hazardous treatment techniques are used, such as open-air burning and acid baths (Anderson, 2021).

There are notable differences in priorities between advanced and emerging economies regarding e-waste management. It is argued that people in emerging economies are more focused on economic factors, while those in advanced economies, having satisfied their basic needs, can consider environmental and social factors (Shahrasbi et al., 2021). In emerging economies, the struggle for survival and meeting basic needs often takes precedence over other concerns. Due to the economic benefits derived from e-waste handling, people are compelled to engage in hazardous practices despite the health risks and environmental damage. The lack of adequate waste management infrastructure and the urgent need for income forces many individuals to resort to informal e-waste handling, often ignoring protective measures due to their financial inability or lack of knowledge. The poor treatment of e-waste, from open burning to acid leaching, is often a result of their survival strategy in a deprived environment (Shahrasbi et al., 2021).

Hicks et al. (2022) painted a picture of the immediate environmental impacts, describing the blatant dumping of e-waste materials in fields, rivers, and ditches. These practices were linked to the contamination of critical resources like water, providing quantifiable evidence of this in the form of heavy metal concentrations exceeding WHO guidelines. Such unregulated e-waste

management can lead to the potential bioaccumulation of pollutants, the contamination of the food chain, and broad environmental exposure (Awasthi et al., 2023).

This theme makes evident the divergence between e-waste management priorities in advanced and emerging economies, emphasising how socioeconomic factors play a big part in the realities facing both. In advanced economies, there is more balance in economic, environmental, and social factors. Whereas in emerging, economic necessity has been seen as a driving force for the harmful practices seen in the informal sector. Interestingly, the informal sector is undeniably linked with the importation of used and end-of-life goods from advanced to emerging economies, however, that is often overlooked when thinking of health and environmental impacts as it is an 'out of sight out of mind' mentality for advanced economies. Shah Khan (2014) stressed the irony of advanced economies exporting their used and end-of-life EEE to emerging countries to satisfy their own environmental regulations or targets when the resulting contamination caused at the final destination will, in due course, be a global issue due to e-waste's universal impact on climate change. This sentiment was reinforced in Maphosa et al. (2020) review which noted that the vast amount of EEE imported to Africa is under the pretence of bridging the digital divide, however, with most of it scrap, it ultimately leaves those receiving it in a worse-off position.

The theme of health and environmental impacts is heavily interconnected with the previous themes. Advanced and emerging economies present differing priorities and approaches to e-waste management, that are largely based on their socio-economic position. The health and environmental impacts are a direct result of the practices evident in the informal sector, which continues to operate due to lax regulations, comprised of a workforce who are unaware of the danger it presents them or others. The discussion section will bring these themes together in a holistic way to better address the research question. Table 3 below shows the interlinked nature of the themes.

	Informal sector in emerging economies	Policy and legislative frameworks	Limited awareness	Health and environmental impacts
Informal sector in emerging economies	-	Weak enforcement and unclear regulations enhance informal sector growth	Limited awareness supports the informal sector through advanced economies ignorance and emerging economies intrinsic need to earn an income to survive	The informal sector contributes to the health and environmental impacts through unsafe work practices such as open-air burning and acid leaching.
Policy and legislative frameworks	Weak enforcement and unclear regulations enhance informal sector growth	-	Policies and legislation suffer due to limited public and institutional awareness	Properly enforced policies can help mitigate health and environmental problems
Limited awareness	Limited awareness supports the informal sector through advanced economies ignorance and emerging economies intrinsic need to earn an income to survive	Policies and legislation suffer due to limited public and institutional awareness	-	Ignorance increases health and environmental risks, while lack of knowledge creates unsafe working conditions without PPE
Health and environmental impacts	The informal sector contributes to the health and environmental impacts through unsafe work practices such as open-air burning and acid leaching.	Properly enforced policies can help mitigate health and environmental problems	Ignorance increases health and environmental risks, while lack of knowledge creates unsafe working conditions without PPE	-

Table 3: Interlinkage of themes

5 Discussion

This chapter provides a comprehensive analysis of the underlying challenges that compromise the effectiveness of current e-waste management strategies globally. The four main themes, (1) 'Informal sector in emerging economies', (2) 'Policy and legislative frameworks', (3) 'Limited awareness', and (4) 'Health and environmental impacts', provide an insightful overview of these challenges.

5.1 Discussion

The four themes are not only interconnected but also reveal a domino effect, with problems in one area prompting issues in another. Policy and legislative frameworks are a vital starting point in the e-waste management chain. A lack of clarity, enforcement, or understanding can significantly hamper effective e-waste management. If these frameworks are not well-designed or not properly implemented, they can unintentionally grow the unregulated informal sector.

On the one hand, the informal sector provides livelihood opportunities and offers a means to manage the rising amount of e-waste ending up in many emerging economies (Okwu et al., 2022). On the other hand, the absence of regulations can lead to severe health and environmental risks. These risks are further amplified by improper handling and disposal of e-waste, often involving hazardous and polluting techniques (Bakhiyi et al., 2018). Limited awareness compounds these challenges. Insufficient understanding of the dangers associated with e-waste and the importance of responsible handling and PPE can contribute to the persistence of harmful practices. While ignorance may seem easier in the short term, it poses long-term risks to health and the environment. Raising awareness can serve as a catalyst for change, encouraging safer and more responsible e-waste handling practices.

A significant point of divergence in e-waste management is the contrasting priorities between advanced and emerging economies (Lu et al., 2018). Advanced economies often have the resources and infrastructure to handle e-waste more responsibly, yet their practices, such as exporting e-waste, can complicate matters in emerging economies (Diaz et al., 2019). Here,

economic needs and the struggle to survive often overshadow environmental and health considerations, creating a disparity that needs addressing at a global level (Chen et al., 2020). Any solution to e-waste management should not only address the problem at the end-of-life stage of electronics but also consider strategies for reducing e-waste generation. Addressing the e-waste management challenge requires sustainable solutions that consider socio-economic realities, embrace educational initiatives, and promote environmental stewardship across all sectors.

The role of the informal sector, particularly in emerging economies, plays a significant part in the challenges of managing e-waste responsibly. As the world continues to rely heavily on digital technology, and with industries adopting and embracing automation, the volume of e-waste generated continues to rise rapidly (Shittu et al., 2019). The informal e-waste sector, often driven by socio-economic circumstances, sees workers resort to hazardous and unregulated e-waste recycling and disposal practices that directly impact their health and the surrounding environment. Despite these impacts, it is a means of livelihood for some, and the decision to be in this line of work is driven by necessity rather than by choice. While improper disposal practices can lead to the contamination of soil, air, and water, it also has valuable materials such as copper, gold and platinum that can be recovered to be sold and/or reused (Ikhlayel, 2017). While the manner in which these materials are salvaged often compromises the worker's health and the environment, it has allowed them the opportunity to make money to support themselves and their families. This scenario sees workers engaging in an activity out of survival while simultaneously harming their health and the environment. Consequently, they are trapped in a harmful cycle.

As such, the solution to better management of e-waste is not as simple as closing down informal recycling as this approach would disregard the socio-economic realities of the workers involved and potentially intensify their marginalisation. Instead, a more inclusive approach is needed that acknowledges these workers and the role they play while working to transition them to more formal ways of working, facilitating a more equitable solution. This could involve appropriate

training being put in place so that these workers are not marginalised further in the process of formalising the informal sector. Additionally, government policies could be developed to incentivise the formalisation of these operations, for example through financial support for small recycling businesses. However, it is important to be realistic about the challenges of such a transition. Not all informal e-waste workers may be willing or able to move into the formal sector, and the loss of flexibility and the potential increase in monitored processes could discourage some from making the shift. Therefore, any interventions proposed need to be designed to tackle health and environmental issues, as well as improve outcomes for the individuals involved.

Policy and legislative frameworks play an essential role in managing the e-waste landscape but often overlook the dynamics of the informal sector. Despite international agreements such as the Basel Convention, which aims to regulate the transboundary movement of hazardous waste, gaps in the legislation and the black market informal sector have allowed for the continuous illegal trafficking of e-waste (Khan, 2016). Regulations instead need to address the informal sector and create frameworks that consider all stakeholders, including those working in the informal sector. EPR has the ability to formalise the responsibility of e-waste to the producer and Governments are critical in the enforcement of such policies, however, enforcement has not been successful. As previously mentioned, the generation rate of e-waste is rising. This, coupled with the increase in device obsolescence and frequent upgrading of technology, has meant that the present policies and legislation are struggling to keep up to date with the growing challenges of e-waste management.

Contributing significantly to e-waste management challenges is a lack of awareness of the associated risks and the ways in which to manage them, which various studies in the literature review detailed. Despite a seemingly simple definition of e-waste as being electrical and electronic waste, the multitude of items that fall into this category range from everyday appliances to industrial machines making it slightly more ambiguous. Awareness is multi-dimensional, from this basic understanding to the more complex aspects - such as the

composition of inorganic and organic components (Bakhiyi et al., 2018). The double-edged nature of e-waste is not often recognised as both a source of income from recyclable materials and a threat to both health and the environment, as seen mainly in the informal sector. Awareness particularly causes challenges for those working in the informal sector who don't understand the need for PPE, resulting in worse outcomes for themselves and those around them (Okwu et al., 2022). Legislative efforts such as the Basel Convention and EPR initiatives are significantly underutilised and underenforced when there is no knowledge of what they mean and how they apply to specific stakeholders. It has led to both inadvertent non-compliance and over-reporting, skewing the available data and creating deficiencies when attempting to make decisions (Anderson, 2021).

The present state of e-waste management challenges is summed up in the health and environmental impacts that are the direct consequences. There is a direct correlation between the informal sector, the unenforced regulations and the lack of awareness contributing to adverse health effects and environmental degradation. As previously mentioned, informal workers who do not utilise PPE are exposing themselves to potential health conditions. These hazardous conditions impact not only the workers but also their families, as these substances can travel on their clothes. Additionally, if the families live close by, they can also be affected by the surrounding affected environment. Again, the management challenge here remains in transitioning the processes used by the informal sector into more sustainable and safe ones.

6 Conclusion

E-waste management presents a network of connected challenges. These issues are wider than the themes of the informal sector, policy and legislative frameworks, limited awareness, and health and environmental impacts. There is an ethical dilemma present. The exportation of e-waste from advanced to emerging nations is not merely a logistical concern; it also raises questions of equity.

E-waste is largely a by-product of the modern digital lifestyle of those in advanced economies, driven by the constant upgrades and desire for the latest electronic products. However, the cost of this lifestyle in advanced economies is to the detriment of emerging economies. While advanced economies can handle e-waste responsibly and regulated, a significant portion of this waste is often exported to emerging economies. Subsequently, e-waste processing becomes a livelihood for marginalised communities, creating severe health and environmental risks due to improper handling and recycling.

This situation introduces an apparent moral dilemma. On one side, technological advancements and consumer convenience lead to the generation of vast amounts of e-waste. On the other side, less affluent parts of the world, driven by the struggle to meet basic needs, bear the brunt of processing this waste. This issue urgently needs to be addressed as a matter of global social responsibility.

In conclusion, e-waste management is a multi-dimensional issue that requires a global solution. This involves developing and enforcing effective policy and legislative frameworks, promoting public awareness, and recognising the role played by the informal sector. It consists in addressing the moral implications of e-waste and seeking more equitable strategies that recognise the realities of e-waste workers and their working environments. This approach will help mitigate the adverse health and environmental impacts of e-waste and ensure that the burden of managing e-waste is shared more equitably across advanced and emerging economies.

6.1 Research Limitations

This research project followed the systematic literature review process, and certain limitations should be considered. The exclusion criteria applied in this research, outlined in the methodology section, may have resulted in the exclusion of relevant studies, limiting the scope of the data analysed. The literature search was restricted to three databases most suitable for the research topic. This may have overlooked potential valuable insights from studies published in other databases.

There are certain limitations to only using secondary data, including that the published studies may have limitations or biases in their methodologies or reporting. Therefore, the conclusions of this research should be considered with these limitations in mind.

Despite these limitations, this research study contributes to the existing body of knowledge by providing an overview of the underlying challenges that compromise the effectiveness of current e-waste management strategies. Future research should address the limitations by incorporating a more comprehensive range of databases and articles for the literature review.

6.2 Future Research

The findings from this systematic literature review provide several opportunities for future research. The complex nature of the global e-waste management issue requires cross-sectoral efforts to explore further and address its implications.

Further research is needed to delve into the multi-dimensions of e-waste awareness. Limited awareness remains a significant challenge in managing e-waste effectively, and research focusing on understanding the nuances of this issue can be instrumental in creating effective educational and awareness campaigns. These campaigns should be targeted, involving various stakeholders such as consumers, e-waste handlers, and policymakers. Each stakeholder plays a distinct role in the e-waste management lifecycle and has a different opinion on what would work best, collaborating these ideas could lead to better outcomes for all. Sensitising consumers in advanced economies about the implications of their e-waste is of equal importance. Advanced economies contribute significantly to e-waste generation due to the high consumption and dependence on electronic goods. Educating consumers about responsible purchasing and disposal behaviours can play a significant role in reducing e-waste. Further research can focus on how best to raise consumer awareness and promote responsible consumption habits.

Addressing the discrepancies in e-waste data collection and reporting is crucial. Future research should look into developing standardised methods for classifying and quantifying e-waste, thus facilitating more accurate and comparable data. This is especially important in emerging economies with significant informal recycling sectors. Research into the socio-economic impacts of e-waste will also be important to understand the balance between the potential financial gains from e-waste recycling and the associated environmental and health risks. This is useful in determining what can inform sustainable policy decisions.

Regarding recommendations, it is clear that regulation and legislation must be more active in e-waste management. While international agreements such as the Basel Convention have made progress in this area, there is room for more comprehensive, universally ratified legislation

addressing e-waste from a global perspective while acknowledging that it is not a one-size-fits-all for each country. This is particularly highlighted in Nigeria, where legislation alone cannot instigate change. Robust enforcement, improved infrastructure, and societal interventions are needed to address the root causes of workers participating in the informal sector. While creating alternative employment solutions can improve the likelihood that workers will transition from the informal to the formal sector.

Lastly, the principles of EPR and the CE could be integrated more firmly into e-waste management strategies. Further studies could investigate how these concepts can be effectively operationalised across different contexts and sectors. This systematic review provides a starting point for future research into the global e-waste management issue, with the aim of contributing to a more sustainable and responsible approach.

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8 Appendix:

8.1 Appendix A: Themes, sub-themes, and open codes

Themes	Sub-themes	Open codes
Informal Sector in Emerging Economies	• Economic and financial situation • Insufficient infrastructure • Misdeclaration of goods • Trans-boundary movement of e-waste	• Absence of infrastructure for appropriate waste management • Informal sector removing WEEE from waste stream before formal sector can obtain it • Countries wanting to be paid for WEEE instead of paying to recycle • Second-hand goods not tested for functionality • Unclear responsibilities for stakeholders • Economic need to work in informal sector – no choice • Uncompetitive collection prices and channel of formal treatment plants • Throwing mobile phones in municipal bins despite takeback schemes • Storing old technology in drawers despite knowledge • Transboundary movement of. e-waste • Pre-processing for small devices like mobiles suboptimal for collecting precious metals • Economic incentive to export to developing countries • Health risks to informal workers
Policy and Legislative Frameworks	• Regulations • Legislation • Standardisation • Extended Producer Responsibility	• An absence of legislation dealing specifically with e-waste • An absence of any framework for end-of-life (EoL) product take-back or implementation of extended producer responsibility (EPR) • Definition of recycling is confusing for targets resulting in an unlevel playing field for EU member states on their reportbacks • Weak legislation and poverty major obstacle in stopping informal sector

		• Transboundary movement • Manufacturer obligations • No single administrative institution fully supervises and executes the issued laws • Too many confusing laws in recent years. no sufficient time to update technology to fit the legislation • Need for harmonisation • Hard to implement EPR due to sheer volume of producers in China
Limited Awareness and Lack of Data	• Education • Knowledge • Lack of data • Unreliable data	• Ignorance of toxicity of e-waste • Limited data availability results in illegal exports to non-OECD countries- tracking of illegal waste cargos a major challenge for regulators • No recycling target. Lack of clarity makes execution difficult for local planning activities • They don't trust the recycling programmes and think the waste is hurting developing countries so they'd rather throw it in their own countries landfill • Lack of environmental awareness campaigns and knowledge on informal sector risks • Awareness campaign effectiveness • Consumer behaviour – hoarding • Public knowledge gap • Nervous about data protection so send to landfill
Health and Environmental Implications	• Informal recycling activity • Priorities • Contamination routes	• Workers in informal sector mostly marginalised groups or children - less economic security and vulnerability leads to barriers in health and safety • Where labour is expensive (developed countries) there is a need for regulations as economic factors will override environmental • In Australia, those managing the NTCRS scheme are autonomous in deciding what to do with waste - greater profit is favoured meaning they send it overseas to developing countries • No monitoring tools when sent to developing countries • Economic necessity • Contamination from e-waste handling

8.2 Appendix B: Themes and related articles

Theme	Author
Informal Sector in Emerging Economies	Bakhiyi, Gravel, Ceballos, Flynn, & Zayed (2018).
	Chen, Faibil, & Agyemang (2020).
	Gollakota, Gautam, & Shu (2020).
	Maphosa, Maphosa, & Tan (2020).
	Okwu, Viza, Hursthouse, & Idoko (2022).
	Osibanjo, & Nnorom (2007).
	Qu, Zhu, Sarkis, Geng, & Zhong (2013).
	Rajesh Ejiogu (2013).
	Shumon, Ahmed, & Islam (2014).
	Wang, Tian, Zhu, & Zhong (2017).
Policy and legislative frameworks	Andersen (2022).
	Dias, Bernardes, & Huda (2019).
	Iqbal, Breivik, Syed, Malik, Li, Zhang, & Jones (2015).
	Lu, Yang, Ijomah, Wu, & Zlamparet (2018).
	Shumon, Ahmed, & Islam (2014).
	Zhang, Ding, Liu, Pan, Chang, & Volinsky (2015).
	Arya & Kumar (2020).

Limited Awareness and Lack of Data	Diedler, Hobohm, Batinic, Kalverkamp, & Kuchta, K (2018).
	Duygan & Meylan (2015).
	Gunarathne, de Alwis, & Alahakoon (2020).
	Khetriwal, Widmer, Kuehr, & Huisman (2011).
	Kwatra, S., Pandey, S., & Sharma, S. (2014).
	Okwu, O., Viza, E., Hursthouse, A., & Idoko, L. (2022).
	Speake, J., & Yangke, L. N. (2015).
Health and Environmental impacts	Andersen, T. (2022).
	Awasthi, Iacovidou, Awasthi, Johnson, Parajuly, Zhao, Mishra, & Pandey (2023).
	Bakhiyi, Gravel, Ceballos, Flynn & Zayed (2018).
	Gunarathne, de Alwis, & Alahakoon (2020).
	Hicks, Dietmar, & Eugster (2005).
	Maphosa, Maphosa, & Tan (2020).
	Shah Khan, Aziz Lodhi, Akhtar, & Khokar (2014).
	Shahrasbi, Shokouhyar & Zeidyahyaee (2021).