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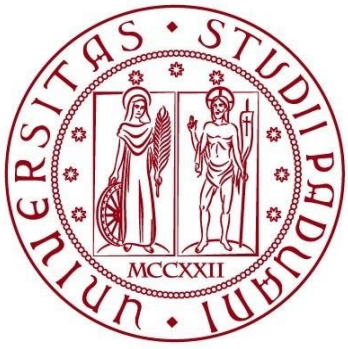

MASTER THESIS

Unveiling the e-waste management situation in Agbogbloshie, Accra Ghana

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Lastly, I want to acknowledge my friends who provided unwavering support during the various challenges and successes encountered throughout this academic journey.

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Dedication

This master's thesis is mainly dedicated to my parents, who have consistently been there for me, providing unwavering support, even during times when I considered giving up. Furthermore, I extend this dedication to Professor Maria Cristina Lavagnolo for her steadfast support, dedication, and inspiration, both directly and indirectly. The rest of my gratitude is directed towards everyone who has played a role in my educational journey, especially the teaching staff at the Department of Civil, Environmental, and Architectural Engineering, and PhD candidate Nzubechi Reginal Muonaka from King Abdullah University of Science and Technology.

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LIST OF ABREVIATION

Ag	Silver
AQI	Air Quality Index
BLLs	Blood Lead Levels
Cd	Cadmium
CDC	Centers for Disease Control and Prevention
Cr	Chromium
CRT	Cathode Ray Tube
Cu	Copper
Cu	Copper
DVD	Digital Versatile Disc
EEE	Electrical and Electronic Equipment
EPA	Environmental Protection Agency
FEF	Forced Expiratory Flow
FEV	Forced Expiratory Volume
FVC	Forced Vital Capacity
IMF	International Monetary Fund

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IT	Information Technology
LED	Light Emitting Diode
NEAP	National Environmental Action Plan
Ni	Nickel
Pb	Lead
PBDEs	Polybrominated Diphenyl Ethers
PC	Personal Computer
PCBs	Polychlorinated Biphenyls
PEF	Peak Expiratory Flow
PM	Particulate Matter
Sb	Antimony
TV	Television
UNEP	United Nations Environmental Program
WHO	World Health Organization
Zn	Zinc
Zn	Zinc

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Abstract

This master's thesis delves into the e-waste management scenario in Agbogbloshie, Accra, Ghana, a region grappling with the consequences of informal e-waste recycling. The study begins by defining e-waste according to the United Nations Environment Program (UNEP) guidelines which state that it comprises information and communication technologies (ICT) and other electrical/electronic equipment that have been discarded or reached the end of their life. This includes devices that rely on electric current or electromagnetic fields for their operation. . Despite Ghana's adherence to the Basel Convention, Bamako Convention, and established waste management laws, implementation remains inadequate. The thesis explores the historical and current trends at Agbogbloshie, West Africa's largest e-waste dumping site.

Examining Ghana's middle-income demographic, the research highlights a preference for second-hand electronics, a trend peaking in the early 2000s due to imports and charitable donations from Western Europe and the United States. Investigating the current state of Agbogbloshie, findings from Dodd et al. (2023) indicate alarming concentrations of metals surpassing international soil quality guidelines, posing environmental and health risks. Steinhausen et al.'s (2022) research establishes the influence of e-waste on heavy metal concentrations in local fish, affecting both the Korle Lagoon and the Atlantic Ocean.

Estimations of e-waste generation vary, with Agbavitor (2018) proposing 798.20 metric tons annually and Owusu-Sekyere et al. (2022) suggesting a broader range of 13,090 to 17,094 tons per annum. The classification of electrical gadgets prevalent at Agbogbloshie is discussed, emphasizing the site's economic significance in Ghana's private sector-driven economy.

The research uncovers the governmental role in the demolition of the site, where permits were sold to e-waste operators for legal operation, contributing to the city's development through taxes. Despite the demolition, illegal e-waste activities persist, expanding beyond Agbogbloshie. The thesis sheds light on the aftermath, revealing the government's lack of remediation efforts for the claimed recovered space.

Analyzing the impact of e-waste on workers and residents, parallels are drawn to global instances, notably in China. The study concludes with recommendations, prioritizing the adoption of Lavagnolo & Grossule's (2018) "3's" approach – Sanitization, Subsistence economy, and Sustainable landfilling – as a comprehensive solution for sustainable e-waste management in Agbogbloshie and beyond.

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Astratto

La tesi del master approfondisce lo scenario della gestione dei rifiuti elettronici ad Agbogbloshie, Accra, Ghana, una regione alle prese con le conseguenze del riciclaggio informale dei rifiuti elettronici. Lo studio inizia definendo i rifiuti elettronici secondo le linee guida del Programma delle Nazioni Unite per l'ambiente (UNEP), che includono le tecnologie dell'informazione e della comunicazione (ICT) e altre apparecchiature elettriche/elettroniche che sono state scartate o hanno raggiunto la fine della loro vita. Ciò include dispositivi che si basano sulla corrente elettrica o sui campi elettromagnetici per il loro funzionamento. . Nonostante l'adesione del Ghana alla Convenzione di Basilea, alla Convenzione di Bamako e alle leggi stabilite sulla gestione dei rifiuti, l'attuazione rimane inadeguata. La tesi esplora le tendenze storiche e attuali ad Agbogbloshie, la più grande discarica di rifiuti elettronici dell'Africa occidentale.

Esaminando la fascia demografica del Ghana a reddito medio, la ricerca evidenzia una preferenza per l'elettronica di seconda mano, una tendenza che ha raggiunto il picco nei primi anni 2000 a causa delle importazioni e delle donazioni di beneficenza dall'Europa occidentale e dagli Stati Uniti. Indagando sullo stato attuale di Agbogbloshie, i risultati di Dodd et al. (2023) indicano concentrazioni allarmanti di metalli che superano le linee guida internazionali sulla qualità del suolo, ponendo rischi per l'ambiente e la salute. La ricerca di Steinhausen et al. (2022) stabilisce l'influenza dei rifiuti elettronici sulle concentrazioni di metalli pesanti nei pesci locali, interessando sia la Laguna di Korle che l'Oceano Atlantico.

Le stime sulla produzione di rifiuti elettronici variano, con Agbavitor (2018) che propone 798,20 tonnellate all'anno e Owusu-Sekyere et al. (2022) suggerendo un intervallo più ampio tra 13.090 e 17.094 tonnellate all'anno. Viene discussa la classificazione dei gadget elettrici prevalenti ad Agbogbloshie, sottolineando l'importanza economica del sito nell'economia guidata dal settore privato del Ghana.

La ricerca rivela il ruolo del governo nella demolizione del sito, dove i permessi venivano venduti agli operatori di rifiuti elettronici per operazioni legali, contribuendo allo sviluppo della città attraverso le tasse. Nonostante la demolizione, le attività illegali legate ai rifiuti elettronici persistono, espandendosi oltre Agbogbloshie. La tesi fa luce sulle conseguenze, rivelando la mancanza di sforzi da parte del governo per ripulire lo spazio rivendicato.

Analizzando l'impatto dei rifiuti elettronici su lavoratori e residenti, si tracciano paralleli con casi globali, in particolare in Cina. Lo studio si conclude con raccomandazioni che danno priorità all'adozione dell'approccio "3 S" di Lavagnolo & Grossule (2018) – Servizi igienico-sanitari,

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Economia di sussistenza e Discarica sostenibile – come soluzione completa per la gestione sostenibile dei rifiuti elettronici ad Agbogbloshie e oltre.

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INTRODUCTION

Electronic waste, as per the UNEP 2007 definition, comprises information and communication technologies (ICT) and other electrical/electronic equipment that have been discarded or reached the end of their life. This includes devices that rely on electric current or electromagnetic fields for their operation.

As outlined in a 2019 report from the United Nations Environmental Program (UNEP), the global generation of electronic and electrical waste (e-waste) amounts to approximately 50 million tons annually. Additionally, the same document reported that during the World Economic Forum in Davos, Switzerland, on 24 January 2019, it was noted that if present patterns persist, the worldwide production of e-waste is projected to soar to 120 million tons each year by 2050.

E-waste poses a significant challenge for developing nations, particularly in Africa and Asia. Advanced countries with thriving technology industries frequently dispose of their obsolete electronics by exporting them to these developing nations, which often lack proper waste management infrastructure. Presently, technology and electrical devices have become integral to various aspects of daily life (Garlapati, 2016). We rely on electronics in our homes, jobs, schools, hospitals, and virtually every facet of our existence. When these electronic devices become outdated in developed countries, Africa and other developing nations sometimes serve as their dumping grounds. In Ghana and other African countries, citizens living abroad transport these electronics back home and sell them as secondhand equipment. Ghana has accepted both the Basel and Bamako Conventions, which oversee the cross-border transportation of electronic waste. A non-expert would inquire about both the Basel and Bamako conventions.

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, established in 1989 and enacted in 1992, is the most comprehensive global environmental agreement addressing hazardous wastes and other types of wastes. It boasts nearly universal participation, with 191 Parties, including Ghana. Conversely, the Bamako Convention, implemented in 1998, is an accord among African nations that prohibits the importation of any hazardous, including radioactive, waste into Africa. It was prompted, in part, by Article 11 of the Basel Convention, which encourages parties to form agreements on hazardous waste at the bilateral,

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multilateral, and regional levels to achieve the convention's goals. The impetus for the Bamako Convention also stems from the Basel Convention's failure to prohibit the trade of hazardous waste to less developed countries (LDCs) and the recognition that numerous developed nations were exporting toxic wastes to Africa, illustrated by cases such as the Koko case in Nigeria and the Probo Koala case in Ivory Coast (UNEP). However, there has been minimal enforcement of these legislations, as noted in studies by Amoyaw-Osei et al. (2011) and Daum et al. (2017). Some of these goods are often overlooked due to individuals' personal interests at the port. Laws exist that prohibit certain electrical appliances based on their age and energy consumption, especially used refrigerators, from being imported into the country.

In Ghana, a significant portion of the population, falling within the middle-income bracket, exhibits a notable preference for used electronic devices over new ones, often due to the perceived high cost of new devices. Besides the issue of elevated electricity consumption, many of these electronic devices tend to become obsolete prematurely. Furthermore, a considerable percentage of the imported electrical goods into the country either malfunction quickly or is already outdated, leading to their disposal in locations that do not meet the criteria for proper landfill sites. Some of these goods, despite being obsolete, end up in these sites due to inadequate or intentional negligence during inspections by both port officials in Ghana and Western countries, a situation that runs counter to the principles outlined in both the Basel and Bamako conventions. Many of these electronic devices contain hazardous substances like mercury, cadmium, lead, chromium, beryllium, and arsenic, as highlighted by Ilankoon et al. (2018), posing potential health and environmental risks to the society. For instance, mercury, a toxic heavy metal contaminant found in obsolete computers and batteries, is known to cause kidney and brain damage, as indicated by Zeng et al. (2017). Lead, which is present in cathode ray tube (CRT) monitors, can lead to irreversible neurological abnormalities, particularly in young individuals.

Over the past decade, the Agbogbloshie e-waste dumpsite has gained notoriety as a repository for electronic waste. Remarkably, there have been minimal efforts to standardize this site according to international norms or explore opportunities for recycling valuable materials for economic gain. The operation of the site is predominantly overseen by informal recyclers, who, like their counterparts in many developing nations, operate without adhering to any established protocols. Research findings have revealed that e-waste intended for recycling in developed nations is often illicitly processed or

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discarded in developing countries, including Ghana (Daum et al., 2017; Odeyingbo et al., 2017; Sander and Schilling, 2010).

Similar to numerous developing and transitioning nations, Agbogbloshie lacks the essential technical standards and treatment systems, such as controlled incineration with flue gas cleaning or comprehensive processing for metals and slag, as emphasized by Kumar et al. (2017). In this locale, informal recyclers partake in what is commonly known as open burning of waste, extracting potentially recyclable or valuable materials like gold, silver, copper, tin, lead, and motherboards from specific electronic devices, including palladium, among others, all without utilizing any protective gear. These practices not only have detrimental effects on the health of settlers and workers around and within the site but also have a significant impact on the environment. Agbogbloshie exhibits one of the worst air quality indexes, with an AQI of 151-200, as reported by the Ghana news agency (GNA, 2023). The normal AQI should hover around 0-50, and 51-100 is considered moderate. Moreover, all the surrounding river bodies have been contaminated, adversely affecting aquatic life, causing the proliferation of mosquitoes that lead to malaria—a significant concern given that fish is a common meat source for many Ghanaians. The groundwater at the site is also polluted, although there hasn't been a well-funded research investigation to determine the extent of contamination. These occurrences result from the poor implementation of legislation regarding waste management practices and the improper disposal of electronic waste. Furthermore, western nations, despite claiming to champion climate change mitigation, waste management, and sustainable development, often turn a blind eye to the importation of goods, especially electronics, into developing countries like Ghana.

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1. Brief history of Agbogbloshie

Agbogbloshie, situated in the heart of Accra, Ghana, is a commercial district located on the Korle Lagoon of the Odaw River. Historically, this area was a wetland teeming with wildlife until the rise of scrap dealing and improper electronic waste recycling activities. Furthermore, it once served as a temporary refuge for those fleeing the Konkomba and Nanumba conflict in 1994. While scrap dealing had its origins in the 1980s, it gained momentum around the 1990s with the establishment of the Greater Accra Scrap Dealers' Association. Over time, urbanization contributed to the area's expansion, attracting individuals seeking to escape poverty in their rural hometowns with hopes of success in Accra.

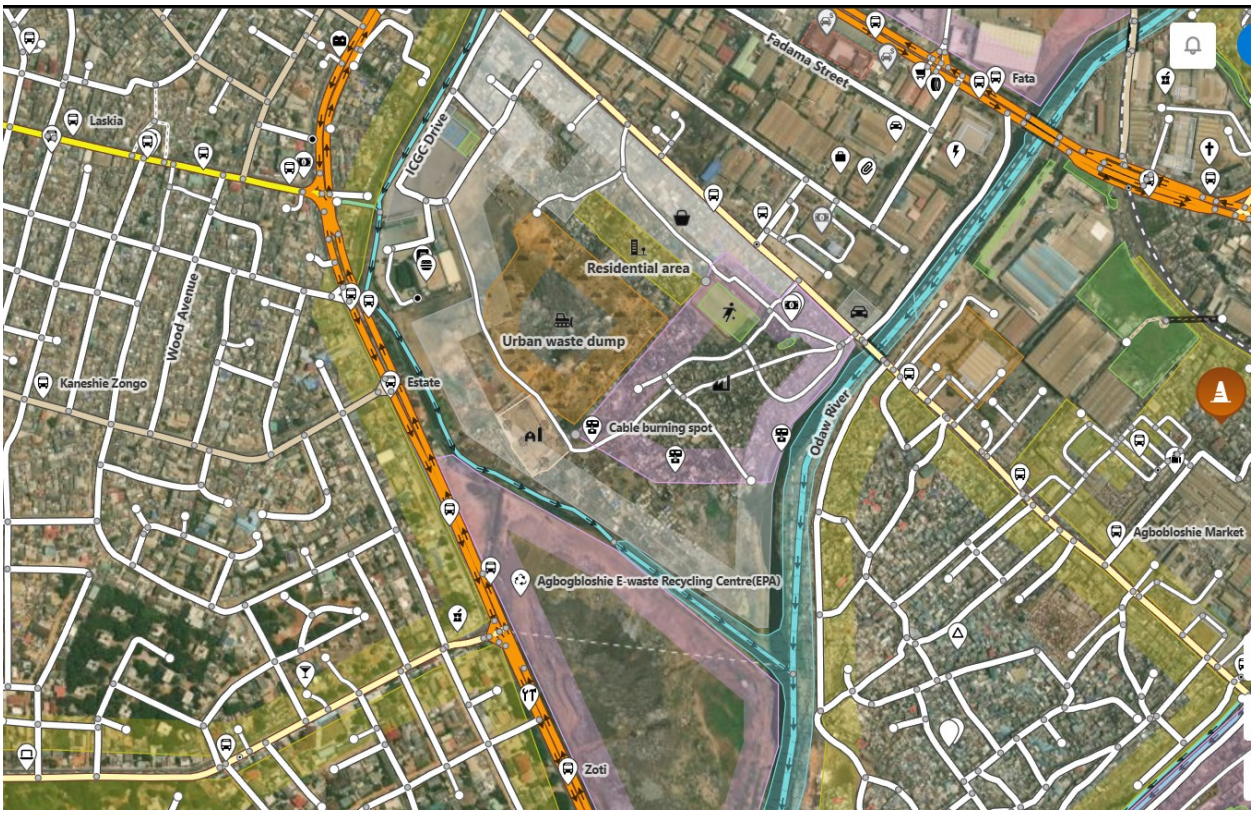

Figure 1 Satellite view of Agbogbloshie e-waste site Copyright Bing map builder

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1.1 Research objectives

The main objective of this research is to unveil and investigate the present conditions and the consequences of electronic waste pollution on human health, the environment, and the social demography in the context of Agbogbloshie e-waste site.

1.1.1 Specific objectives

The study specifically sought to:

1. The current situation of Agbogbloshie e-waste site. *(Environmental conditions)*
2. The demolition and what lead to it.
3. The plan of the government, do they plan to remediate the site before any project takes place?
4. The economic impact of the site on the local economy.
5. Examine the typical health conditions associated with e-waste exposure.

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2. MATERIALS AND METHODOLOGY

In the methodology section of the thesis exploring the Unveiling the e-waste management situation in Agbogbloshie, Accra Ghana, data for this master's thesis was gathered from a diverse range of relevant existing literature. To assess the current socio-economic demographics at the E-waste site, research questionnaires were incorporated into the methodology. These questionnaires were administered by a third party due to logistical constraints. The interviews conducted for the questionnaires were conducted in three languages: Twi, Ga, and English, given that a significant portion of the population, including workers and residents, hails from the northern region of Ghana.

However, the ongoing government-led decongestion process at the site created a sense of apprehension among the residents and workers. Consequently, many declined to participate in the interviews, as they feared the interviews might be perceived by the government as a reason for eviction from their homes and workplaces.

From an initial selection of over 102 literature sources, the final list was distilled to 17 pertinent sources, guided by the insights gained from the interviews. The focus of the literature search was primarily on works investigating issues related to legislation on waste management in Ghana and the world, historical and the current trends around the site, the circular economy of Ghana and other western and developing countries and other health relating topics like Volatile Organic Compounds (VOCs), Particulate Matter (PM), and other elements associated with air pollution. Additionally, a valuable conversation with a medical professional played a role in shaping the decision to narrow down the search for literature pertaining to air pollution.

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2.1 Methodology

The exploration of literature on the subject "Unveiling the e-waste management situation in Agbogbloshie, Accra Ghana" was carried out with great care to guarantee a thorough and all-encompassing method. The subsequent measures were implemented during the literature search:

1. Identifying primary databases and libraries:

The first phase entailed recognizing well-known databases that house scholarly and scientific literature pertaining to environmental health, e-waste, and human health. The databases chosen were:

- ScienceDirect: A vast collection containing scientific journals, articles, and conference papers.
- Scopus: A multidisciplinary database providing access to peer-reviewed literature and conference proceedings.
- Web of Science: A wide-ranging citation index that includes scholarly articles and conference proceedings.
- PubMed: Articles related to medical research on the topic were referenced from this source.

2. Development of Search Keywords:

A compilation of appropriate keywords and search terms was created to encompass all aspects of the research topic. The chosen keywords consisted of "e-waste," "electronic waste," "human health, “environmental effects”, economy”, demolition’ "health effects," "Agbogbloshie," and "Ghana." Additional synonyms and related terms were integrated to expand the search scope.

3. Inclusion of News Outlets and Reports:

To gather information beyond academic sources, reputable news outlets and official reports related to e-waste and the theme of the thesis were included in the search. These sources provided valuable insights from a broader perspective.

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2.2 Research questionnaires

The research questionnaires aided in gathering data by guiding the choice of literature to review, ensuring consistency, and facilitating the collection of objective information. They yielded valuable feedback and perspectives from participants, enhancing the understanding of their opinions and experiences. The survey was carried out with the assistance of a third party, which integrated local languages and English to conduct the survey.

Section 1: Demographics

1. Gender:
    - Male
    - Female
2. Age:
3. Educational Background:
    - No formal education
    - Primary school
    - Secondary school
    - Tertiary education
    - Other (please specify)
4. Which part of the country are you from?
5. How long have you been involved in e-waste recycling at Agbogbloshie?

In the initial section of the questionnaires, the questions were designed to establish a friendly approach and lay the foundation for the subsequent inquiries.

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Section 2: E-Waste Recycling Activities 5. What types of electronic waste materials do you typically work with?

6. How do you obtain e-waste materials?
    - Purchasing
    - Collecting from sources
    - Other (please specify)
7. Do you engage in open burning of e-waste materials? (Yes/No)
8. What safety measures do you take while handling e-waste materials?

    These inquiries were posed to ascertain their direct engagement in the e-waste recycling industry and to identify the specific category to which they belong.

Section 3: Economic Situation 9. Can you estimate your average monthly income from e-waste recycling?

10. Have you observed any changes in your income due to changes in the e-waste recycling business recently? (Yes/No)
11. Are there any specific challenges or financial struggles you face as an e-waste recycler in Agbogbloshie?

    These queries were posed to understand their financial situation, helping us determine if they are reaping the rewards of their efforts. The questions were presented in a friendly manner.

Section 4: Health 12. Have you experienced any health issues you believe are related to e-waste recycling? (Yes/No)

13. If yes, please specify the type of health issues.
14. Have you ever received any health check-ups or medical assistance related to your e-waste recycling activities? (Yes/No)

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15. What kind of support or resources would improve your overall health and well-being as an e-waste recycler?

    These inquiries aimed to understand their present health condition. The primary purpose of these questions was to determine whether they had observed any significant alterations in their health since working on the site and whether they engage in routine health checkups, a practice uncommon in Ghana where many people tend to depend on self-medication.

Section 5: Additional Comments 16. Please provide any additional comments or suggestions regarding e-waste recycling and your experiences in Agbogbloshie.

Further remarks were included to invite their perspectives, aiming to foster a more amicable and equitable conversation. This segment also plays a role in shaping certain remarks within the conclusions and recommendations.

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3. RESULTS AND DISCUSSION

In this chapter, we will scrutinize diverse findings from various sources to determine the latest statistics concerning the Agbogbloshie site. These findings align with the research goals and questions. Subsequent to the analysis of the results, we will engage in a discussion to provide a more profound understanding of these discoveries.

In the upcoming sections, we will explore both quantitative and qualitative data gathered from various literature sources. These findings illustrate the complex and multifaceted nature of the e-waste issue in Agbogbloshie, offering valuable insights into both the scale of the problem and its far-reaching consequences. The results and analysis section will be divided into two parts. The initial that is the "Social demography" part will openly address historical and current events within and beyond the site, delving into the economic repercussions of e-waste activities and discussing various relevant topics. The second and final part will be exclusively dedicated to examining the impact of e-waste on human health within Agbogbloshie. Specific findings will be compared with similar studies conducted in various landfills or sites in different countries.

3.1. Social Demography

3.1.1 History of Agbogbloshie

In 1957, the Gold Coast, now known as Ghana, gained independence from British rule, and Osagyefo Kwame Nkrumah became the first Prime Minister. To foster economic development, the country initiated a modernization strategy, shifting from a colonial export economy to creating import-substitution industries (Aryeetey, Harrigan, and Nissanke 2000). Nkrumah aimed to transform Ghana into an industrialized nation, leading to the establishment of Tema city and the completion of its harbor in the 1960s. This development facilitated import and export activities, contributing to the population growth of Accra, which increased from 388,396 in 1960 to 636,667 in 1970 and 969,195 in 1984 (Yankson and Bertrand 2012).

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The urban-focused industrial development strategies pursued by the government made Accra economically and socially appealing, attracting migrants seeking opportunities during the industrial revolution. Nkrumah envisioned Accra as a livable capital with open green spaces, including what is now known as Agbogbloshie. His plan designated areas for schools and public parks, emphasizing the importance of open space, especially in densely populated areas like James Town.

However, Nkrumah's plans were disrupted when he was overthrown. By the 1980s, Accra was already overpopulated, and in the 1990s, scrap dealing gained momentum with the establishment of the Greater Accra Scrap Dealers' Association. The influx of refugees from the Konkomba and Nanumba conflict in 1994 further contributed to the settlement and informal business activities in Agbogbloshie. The scrap business expanded in the early 2000s, driven by economic challenges during Ghana's engagement with the International Monetary Fund (IMF).

Notably, the area where Agbogbloshie is located has been part of the Ga people's history since the 16th century when early settlers began inhabiting the region near the Korle Lagoon (Government of Ghana, Ministry of Housing 1958, 28).

3.1.2 The land

Agbogbloshie, located in the heart of Accra, Ghana, along the Korle Lagoon of the Odaw River, has undergone significant changes. Originally a wetland with a diverse ecosystem, the area has been altered due to urbanization, industrialization, and informal settlement. Unfortunately, it has become synonymous with the dumping and recycling of electronic waste (e-waste), resulting in soil contamination. E-waste, known for its high content of toxic metals, polyaromatic hydrocarbons (PAH), PCBs, polybrominated diphenyl ethers (PBDEs), and various pollutants, negatively impacts the soil and its microbial communities. Wong et al.'s research in 2007 emphasizes the adverse effects of e-waste on soil fertility and microbial life.

A recent study by Dodd et al. (2023) found that Agbogbloshie, a hub for informal e-waste recycling, has concentrations of metals exceeding international environmental soil quality guidelines. Specifically, levels of As, Cd, Cr, Cu, Mo, Ni, Pb, Sb, Sn, and Zn were higher than recommended. Although surrounding communities showed lower concentrations, certain locations exceeded

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guidelines for residential land use, particularly for Cd, Cr, Cu, Sb, and Zn. Notably, Ag, Cu, Pb, Ni, and Zn were highly bio accessible. Leachate from e-waste contaminants, especially metals, can seep into water bodies, affecting aquatic organisms. Given Agbogbloshie's proximity to the Odaw River and Korle Lagoon, this contamination can impact fishermen in the Atlantic Ocean.

Moreover, Steinhausen et al.'s research in 2022 revealed that heavy metals considered Waste Electrical and Electronic Equipment (WEEE) such as Co and Pb, were more concentrated in fish from the Korle Lagoon than in fish from Accra markets, indicating the influence of the e-waste site. Metals like As, Hg, Cr, and Pb significantly increased health risk hazards. The study, adopting a precautionary approach, highlighted the potential harm from daily consumption of certain fish, especially pompano from the Korle Lagoon, due to elevated levels of arsenic, lead, and mercury. Health implications varied based on the species consumed, frequency, and duration of exposure.

3.1.3 The e-waste

At the outset of the fourth republic, around the early 2000s, Ghana, like many other African nations, sought assistance from the International Monetary Fund (IMF) and the World Bank. However, this financial aid came with consequences and stipulations. The requirements compelled the government to privatize state corporations and liberalize the importation of foreign products, displacing locally manufactured goods. Consequently, this marked the beginning of a surge in electronic waste (e-waste) in the country.

Ghanaians living abroad began introducing secondhand products into the system. Numerous electronic devices from the Western world, such as PCs, TVs, irons, and other electrical gadgets, were imported as secondhand items without assurance of their functionality. Many of these products ended up at Agbogbloshie or other undisclosed informal e-waste sites. In addition to citizens in the diaspora, several Western countries, including America and Western European nations, reportedly intentionally dispose of their electrical waste in less developed countries, especially Ghana, as per Bloomberg news.

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Upon arrival at Agbogbloshie, the imported electronic gadgets undergo sorting. Those deemed non-functional, locally referred to as 'condemn,' are dismantled, and valuable materials like copper, aluminum, motherboards, circuit boards, etc., are extracted and sold for refurbishing other products. The remaining materials become waste, and due to the absence of a designated landfill; they are burned. Ghana lacks a well-equipped e-waste facility for the recycling of electronic waste.

3.1.4 Legislation on E-waste

In addition to the provisions outlined in Article 36 (9) of the 1992 Constitution of Ghana, falling under the Directives of Principles of State Policy, the responsibility for Economic objectives and Development mandates the State to undertake necessary measures for the protection and preservation of the national environment for future generations. It is also directed to seek collaboration with other States and entities to safeguard the broader international environment for humanity. Despite Ghana adopting various legislations such as the Basel and Bamako Conventions to address waste management, adherence to these laws remains deficient, as the governing authority fails to enforce them, and transgressors go unpunished. This normalization of non-compliance is pervasive. The adoption of the National Environmental Action Plan (NEAP) in 1991 articulated Ghana's environmental policy, aiming to significantly enhance the quality of life, living conditions, and physical surroundings for both present and future generations. As per this policy, the State is obligated to implement effective procedures to restrict the use and importation of potentially toxic substances, including Electronic and Electrical Equipment (EEE), while also emphasizing pollution control measures.

3.1.5 Estimations of e-waste generation in and Agbogbloshie Scrapyard

Electronic waste, commonly referred to as e-waste, is frequently transported in mixed loads to the Scrapyard where informal actors fail to distinguish between scrap and electronic waste. On-site, there is a lack of proper equipment for the input and documentation of data regarding the type of metal or goods entering the site. To address this issue, many researchers attempting to estimate the

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volume of e-waste at Agbogbloshie typically develop data sheets for the documentation of discarded electrical and electronic equipment upon their arrival at the dumping site. These sheets encompass information such as product types, quantities, and the mode of transportation for the waste, varying based on the volume of waste brought in.

Agbavitor (2018) conducted a comprehensive study at the University of Ghana, revealing that approximately 798.20 metric tons of waste are deposited at the Agbogbloshie dumpsite annually through three entry routes. Another study by Owusu-Sekyere et al. (2022) suggests a wider range, estimating e-waste generation at the Agbogbloshie Scrapyard to be between 13,090 t/a and 17,094 t/a. However, the reliability of data concerning the total e-waste generation within the Agbogbloshie e-waste site is questioned due to inconsistencies in the data. To delve deeper into the quantification of e-waste in Ghana and the Agbogbloshie Scrapyard, additional literature reviews are presented in the following table (Agbavitor, 2018; Owusu-Sekyere et al., 2022).

Table 1 literature reviews related to the quantification of e-waste in Ghana and the Agbogbloshie Scrapyard.

E-waste	Area and frame	Method	Reference	Year
179,000	Total e-waste generation Ghana	Socioeconomic Assessment	(Schluep et al., 2012)	2009
99,283	Recycled in the informal sect in Ghana (reflects about 9 97% of total e-was generation)	Survey, Field Stu	(Amoyaw-Osei et a 2011)	2011
26,216	Total e-waste generation Ghana	Trade statistics	(Bald´e et al., 2015)	2014
39,000	Total e-waste generation Ghana	Trade statistics	(Bald´e et al., 2015)	2016
52,900	Total e-waste generation Ghana	Trade statistics	(Forti et al., 2020)	2019

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3.1.6 Classification of Electrical and Electronic Waste

Electrical and electronic waste, commonly referred to as e-waste, can be categorized into various groups based on different criteria, which encompass the type of devices, their origin, and the potential environmental consequences. The following are typical classifications for e-waste:

Equipment Types:

a. Major Household Appliances: Encompassing items like refrigerators, washing machines, and air conditioners.

b. Small Household Appliances: Such as toasters, microwaves, and vacuum cleaners.

c. Information Technology (IT) and Telecommunication Devices: Encompassing computers, laptops, mobile phones, and networking equipment.

d. Consumer Electronics: Including televisions, DVD players, and audio devices.

e. Illumination Fixtures: Such as fluorescent lamps and LED bulbs.

f. Toys, Entertainment, and Sporting Equipment: Encompassing electronic toys and gaming consoles.

g. Medical Apparatus: Such as diagnostic and monitoring devices.

h. Monitoring and Control Instruments: Such as thermostats and smoke detectors.

i. Automated Dispensing Systems: Including vending machines.

Origin of Generation:

a. Household E-waste: Referring to discarded electronic devices from residential homes.

b. Business and Commercial E-waste: Comprising e-waste generated by companies and commercial establishments.

c. Industrial E-waste: Stemming from manufacturing processes and industrial operations.

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This classification aids in understanding the diversity of e-waste and how it can be managed effectively.

3.1.7 The Economy (Informal sector)

Ghana's economic landscape is heavily influenced by the private sector, with limited government impact on the national economy. However, the illicit waste recycling activities at Agbogbloshie significantly contribute to Ghana's economic development. The Agbogbloshie scrap processing site operates within a dynamic informal space economy, where commercial, industrial, and residential zones intersect. This waste site plays a crucial role in the local economy, particularly given the high unemployment rate in Ghana.

A considerable portion of the youth in Ghana finds employment at the e-waste site, diverting them from engaging in social vices. The site is populated by local, self-sponsored entrepreneurs who not only recover valuable materials from discarded electronics but also engage in the production of coal pots, a popular cooking utensil in Ghana and other West African countries. Additionally, these artisans manufacture cooking pots from melted metals, selling them in the local market for around 95 Ghana cedis (7-8 euros) each.

These e-waste workers contribute to the local economy by paying city taxes, collected by the Accra Metropolitan, on a yearly basis (approximately 30 cedis or 2 euros and 30 cents). Moreover, kiosk and street hawkers associated with the e-waste industry pay daily taxes of 1 Ghana cedi (0.08 cents). The products crafted by these artisans are sold in the local market, further bolstering the Ghanaian economy.

Furthermore, the government benefits financially from the importation of secondhand goods through the port, as import duties are imposed. Ghana's port is known for being one of the most expensive for importing goods from abroad, prompting some to prefer Togo's duty-free port. However, recent decongestion efforts by the government have displaced many artisans, intensifying unemployment challenges, especially among the youth. This shift has led to negative consequences,

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such as young girls previously employed as load carriers turning to prostitution, locally known as Ashawo. The multifaceted impacts of e-waste activities on the local economy,

employment sector, and social dynamics underscore the complex interplay of informal economies and government intervention.

Figure 2 local artisan producing coal pot from melted metal from a discard e-waste. https://www.youtube.com/watch?v=qpGXsHJwFGE

3.1.8 Current situation around the site

On July 1st, 2021, the government of Ghana, led by the Greater Accra Minister Mr. Henry Quartey, along with armed military personnel and bulldozers, arrived at the Agbogbloshie E-waste site to assist in the decongestion process of both the Agbogbloshie e-waste site and the onion market site. This action occurred shortly after a week of the Basel Convention webinar on E-waste management, during which the Agbogbloshie site was a major topic of discussion. Three months later,

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on October 8th, the Minister, in a radio interview on Asaase radio, mentioned that the government had plans for the site that would benefit the region, that is why the erection of a protective wall around the site.

Before the demolition exercise, the market sellers were issued a notice by the government to relocate to an assigned area, which they declined due to its distance and potential market challenges. Now, two years later, the entire area remains heavily polluted. The government has yet to demonstrate any tangible progress or indication of a project. Instead, the site is now marked by piles of waste materials and human waste. E-waste activities have not ceased entirely; they have shifted to different locations, including among slum residents in the vicinity and other parts of Accra and Tema. Agbogbloshie continues to be highly polluted and can be considered one of the most contaminated areas in Ghana.

Figure 3 An aerial photo taken on 11 June 2021 shows the Agbogbloshie scrapyard before it was demolished 20 days later. Copyright © Muntaka Chasant.

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Figure 4 An aerial photo taken on 28 March 2022 shows the reclaimed Agbogbloshie scrapyard site Copyright © Muntaka Chasant

3.1.9 The Demolition of the site

Agbogbloshie, a longstanding home and livelihood for thousands of residents and workers since the late 90s, witnessed a significant and unexpected turn of events on July 1, 2021. The Accra Metropolitan Assembly, led by regional minister Mr. Henry Quartey and accompanied by military personnel, carried out a forceful demolition of the community using bulldozers. This event unfolded amidst violence from enraged residents and workers. As reported by Muntaka.com, the government's failure to notify the residents about relocation plans, with prior warnings limited to onion sellers in closer proximity, heightened tensions.

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Following the demolition, the razed structures were set ablaze and left unattended, drawing resentment from victims who accused the government of deception, emphasizing that many workers held licenses issued by the Environmental Protection Agency of Ghana. The demolition coincided with the Basel Convention, where Agbogbloshie was a prominent topic of discussion. Two years after the demolition, the land remains un-remediated, while the government outlines plan for constructing state-of-the-art facilities intended to benefit the community.

Despite these plans, the site still grapples with contamination issues, prompting pleas from the affected populace for government intervention. The community seeks the establishment of a modern e-waste recycling facility, not only for employment opportunities but also to foster a more sustainable environment. This narrative encapsulates the ongoing struggle of Agbogbloshie's residents and workers, highlighting the need for urgent remediation measures and the establishment of facilities aligned with environmental sustainability.

Figure 5 A victim affected by the demolition is displaying the permit issued by the Environmental Protection Agency of Ghana, allowing them to engage in their scrap business. Copyright © Muntaka Chasant

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3.1.10 Aftermath of the demolition of the site

Despite the e-waste site being decongested approximately two years and five months ago, there has been no effort to remediate the site, and settlers are seen returning. The e-waste recyclers have shifted to the other side of the lagoon, opposite the location where the government has erected a concrete wall around their previous center of activities. The new e-waste center is experiencing increasing congestion as a result of recyclers returning due to unemployment and economic hardship. Initially, they practiced discreet e-waste recycling to evade government attention, but it is gradually reverting to its previous state. The site remains polluted and has now become a haven for criminals as well.

Figure 6 current situation of the site after the decongestion copyright https://www.youtube.com/watch?v=sTio_0rwR1s&t=502s

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Figure 7 picture of the wall erected by the government copyright https://www.youtube.com/watch?v=sTio_0rwR1s&t=502s

Figure 8 current hustle inside the e waste site copyright https://www.youtube.com/watch?v=sTio_0rwR1s&t=502s

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Figure 9 Picture showing people still practicing open burning near the river copyright https://www.youtube.com/watch?v=sTio_0rwR1s&t=502s

Figure 10 picture of a recycler extracting copper from obsolete electronic copyright https://www.youtube.com/watch?v=sTio_0rwR1s&t=502s

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3.1.11 Results from the research survey (Research questionnaires)

In this segment, 36 individuals willingly took part in the survey, while a significant portion of the population refrained from participating due to concerns about the current situation on the site. Many believed that the survey data might be shared with the government, possibly leading to actions aimed at eviction. The research survey encompassed five sections, starting with demography. Out of the 36 participants, 22 were girls, constituting 61.11%, and the remaining 14 were boys, representing 38.89%. All the girls were from the Northern part of Ghana and had migrated to Accra to work as market aides (kayayo), with a surprising majority being senior high school graduates (13) displaying a commendable command of the English language; the rest were junior high school graduates and school dropouts. The male participants, hailing from various parts of the country, included 8 senior high school graduates, 3 recent university graduates, and 3 school dropouts expressing no interest in education, spanning ages from 17 to 31.

The subsequent section focused on E-Waste Recycling Activities, revealing that the girls predominantly worked as porters, while the surveyed boys were mostly engaged as scrap dealers. The scrap dealers openly admitted to practicing open burning after dismantling the scrap. The following section delved into their economic situation, indicating an average monthly income ranging from 300 to 550 Ghana cedis, equivalent to approximately 23.57-39.28 euros. The subsequent segment addressed health, with most participants resorting to self-medication, a common practice in Ghana due to challenges in the health sector. Regular checkups were deemed expensive and beyond their budget.

The final part of the survey provided an opportunity for additional comments, and a prevalent sentiment was that the government should facilitate the establishment of a proper recycling center, offering training and employment opportunities in the waste industry. Additionally, there was a call for the construction of a material recovery facility.

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3.2 Results from different dissertations on health issues

3.2.1 Effects of Particulate Matter on human health

The adverse effects of electronic waste or e-waste on human health have been the focus of many research studies. E-waste is a growing problem around the world as the consumption of electronic devices continues to increase. The disposal of obsolete electronic devices releases hazardous chemicals such as lead, cadmium, and mercury, posing a threat to the environment and human health. The impact on human health is of particular concern, given that electronic devices are ubiquitous and may contain heavy metals and toxic chemicals that release harmful fumes and particles when burned or disposed of improperly. Considering this, several dissertations have been conducted to investigate the effects of e-waste on human health, seeking to assess the extent of exposure, the types of diseases and illnesses that e-waste exposure can cause, and ways in which the effects can be mitigated. This paper will review and synthesize the key findings and conclusions from a selection of dissertations on the impact of e-waste on human health.

Commencing with the results section on health issues, we will examine $PM_{2.5}$, which refers to fine particulate matter. $PM_{2.5}$ is a type of air pollution composed of extremely small particles or minute liquid droplets suspended in the air, with each particle measuring 2.5 micrometers or less in size. These minute particles are of such a tiny scale that they can be inhaled deeply into the respiratory system and, in certain instances, may even enter the bloodstream, posing potential health risks to individuals.

In our research, we will connect our findings to the current health issues and trends in Agbogbloshie. We will commence our analysis by reviewing a study conducted by Amoabeng Nti et al. in 2020. Their introductory section outlines the research objectives, which primarily aimed to investigate the relationship between the concentrations of particulate matter (PM) with diameters of 2.5 micrometers, 2.5–10 micrometers, and 10 micrometers in the breathing zones of informal e-waste laborers at Agbogbloshie and their lung function. The researchers conducted a longitudinal cohort study with three repeated assessments involving a total of 207 participants. This cohort consisted of 142 healthy e-waste workers from the Agbogbloshie scrapyard and 65 control participants from Madina-Zongo in Accra, Ghana. The study involved the measurement of various lung function

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parameters, including Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV1), FEV1/FVC ratio, Peak Expiratory Flow (PEF), and Forced Expiratory Flow between 25% and 75% of FVC (FEF 25-75). Additionally, the research measured concentrations of PM (2.5, 2.5–10, and 10 μm), accounting for seasonal variations. Socio-demographic data, information on respiratory exposures, and lifestyle habits were collected through structured questionnaires. Subsequently, the researchers employed random effects models to investigate the impact of PM (2.5, 2.5–10, and 10 μm) on lung function.

As per their investigation, the findings regarding the impact of PM exposure on lung function revealed the following results: PM concentrations consistently ranged from 2 to 3 times higher among e-waste workers in comparison to the control group. The median and interquartile range (IQR) values of PM concentrations (2.5, 2.5–10, and 10 μm) during all three seasons at both study sites exceeded the air quality standards set by the WHO, which are 25 μg/m3 and 50 μg/m3 for a 24-hour mean, as well as the average $PM_{2.5}$ concentration levels within the country, which stand at 35 μg/m3.

Additionally, their research indicated that the more substantial reductions in smaller airway parameters (PEF and FEF25-75%) suggest that e-waste workers might face an elevated risk of developing small airway diseases such as occupational asthma, bronchitis, bronchiolitis, and COPD due to airway obstruction. These small airways, known as bronchioles, seem to be especially susceptible to obstructive diseases because of their narrow size.

In a different study focusing on $PM_{2.5}$ exposure and its impact on pediatric health in e-waste dismantling areas, conducted by Zeng et al. in 2022, the research reveals that children residing in e-waste dismantling areas within Guiyu, China, exhibit elevated levels of heavy metals and organic pollutant metabolites in various bodily fluids and tissues, including blood, placenta, urine, feces, and umbilical cord. This study also highlights that the inhalation of $PM_{2.5}$ poses a significant threat to the physical and mental well-being of these children.

Another study by Thongkaow et al. in 2022 has reported similar findings, aligning with the observations made regarding the unregulated open burning of e-waste in Agbogbloshie, Ghana. Their research indicates that the average exposure concentrations of total PCBs (Polychlorinated Biphenyls) in both particle phases (PM2.5–10 and PM2.5) and gas phases were notably higher among workers involved in burning wires compared to those engaged in dismantling bulky, small, and internal e-waste components. PCB congeners, particularly those with lower chlorine content such as PCB-28, -52, -77, -81, -105, -118, and -126, were the dominant species found during e-waste

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dismantling activities. Specifically, PCB-28 and -77 were prevalent co-congeners associated with mechanical dismantling, while PCB-52, -118, and -126 were the primary species emitted during burning operations.

Furthermore, the study revealed that workers exposed to PCBs from burning wires faced a significantly higher estimated lifetime cancer risk, approximately 2.5- to 3.3-fold greater than those involved in the dismantling of bulky, small, and internal e-waste components. Consequently, it is recommended that workers use high-efficiency respiratory protection masks to minimize direct exposure to PCBs and reduce their potential risk of developing cancer.

Table 2 Comparison of the average total PCBs concentration in e-waste dismantling sites ((ng/m3)

Site Study	Sampling point	Samples $PM_{2.5-10}$	Samples PM_2	Gas	Reference
Buriram, Thailar	Dismantling site	53.23 ± 28.4	58.96 ± 19.57	43.53 ± 11.74	Thongkaow et al. (2022)
	Open burning site	54.48 ± 18.9	213.35 ± 61.83	213.35 ± 61.83	
Guiyu, China	Dismantling site	-	14.8 ± 7.9	4.7 ± 4.2	Xing et al. (2009)
	Open burning site	-	57.3 ± 50.1	414.8 ± 355.5	

3.2.2 Effects of Blood Level Concentration on human Health

Given our involvement with electronic waste, we are inevitably exposed to chemicals that can enter our bodies through various pathways. Among the chemicals commonly encountered by e-waste workers is lead. Research studies have identified the presence of lead in our bloodstream. Blood lead levels, as defined by the CDC, indicate the concentration of lead in a person's blood, usually measured in micrograms of lead per deciliter of blood (µg/dL). This measurement serves as an indicator of lead exposure and aids in evaluating the potential health hazards linked to lead exposure.

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In this second phase of our analysis, we will examine the impact of lead present in our bloodstream on the health of individuals, whether they are e-waste workers or residents of the Agbogbloshie e-waste site. The entry of lead into our bloodstream can transpire during e-waste recycling and disposal processes, through various routes, primarily due to exposure to lead-containing materials commonly found in electronic devices. Some of the circumstances in which lead exposure can manifest at e-waste sites encompass dismantling and burning activities. Lead exposure warrants significant concern due to the toxic nature of lead as a heavy metal, which can result in severe health repercussions, especially affecting the neurological and developmental well-being of children, as well as the overall health of adults.

Let us examine and assess a research study conducted by Amankwaa et al. (2017). In this research, they investigated the influence of informal e-waste processing on the blood lead levels (BLLs) of e-waste worker and non-e-waste laborers, primarily females engaged in activities supporting the Agbogbloshie e-waste site. The study also examined how lead exposure correlates with socio-demographic and occupational characteristics. A total of 128 blood samples were subjected to lead level analysis. Interestingly, the average BLL for non-e-waste workers (3.54 μg/dL) was marginally higher than that of e-waste workers (3.49 μg/dL), despite observing a wider range of higher BLLs among e-waste workers (ranging from 0.50 to 18.80 μg/dL) compared to non-e-waste workers (ranging from 0.30 to 8.20 μg/dL). It was noted that individuals involved in e-waste burning tended to exhibit the highest BLLs. Generally, the BLLs fell within the ABLES/US CDC reference level of 5 μg/dL. However, 12.3% of the workers displayed elevated BLLs, defined as BLLs ≥ 5 μg/dL.

According to the data they presented in their study, there were 128 participants and 81 were known to be associated with e-waste activities while 33 were known as non-e-waste workers. Upon combining both e-waste workers and non-e-waste workers, the resulting group comprises 83 males and 31 females, totaling 114 out of 128 participants. Additionally, there was a control group comprising 14 individuals working in office-based occupations unrelated to e-waste, resulting in a total of 128 participants.

The next step is to make a simple calculation and then convert the number of the participants and the gender categories into percentages then proceed to turn them into a pie chart.

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To calculate the percentage of 83 out of 114, you can use the following formula:

(Number of Controlled / Total Population) * 100 Percentage of Controlled Group

= (114 / 128) * 100 = 89.06%

Male Percentage = (83 / 114) * 100

Male Percentage ≈ 72.81%

So, 83 is approximately 72.81% of 114.

Female Percentage = (31 / 114) * 100

Female Percentage ≈ 27.19%

So, 31 is approximately 27.19% of 114.

The findings indicate that employees working in the burning sector of the e-waste site face a higher risk of lead exposure, and the level of harm is directly correlated with the hours worked and the years spent in this line of work. Additionally, it is evident that individuals not directly involved in e-waste management may also be at risk of exposure through secondary contact. This is not unexpected since the e-waste site is located near one of the largest local grocery markets in the capital city. Furthermore, other chemicals come into contact with the surroundings through the air, leading to contamination of the food sold within the market.

In a study conducted by Zeng et al. (2020), it was found that exposure to lead from e-waste has detrimental effects on human health, including impairments in physical and nervous development. Their research highlighted that lead exposure could result in various health issues encompassing growth and developmental problems in children, as well as affecting the cardiovascular, immune, nervous, respiratory, reproductive, skeletal, and urinary systems. Furthermore, the authors demonstrated a significant health disparity between regulated e-waste sites Haojiang and non-regulated site Guiyu, China. Based on my personal observations, it is evident that many children at the Agbogbloshie e-waste site exhibit these health issues and often appear malnourished, underscoring the adverse impact of lead exposure on e-waste workers.

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Table 3 The effects of lead exposure from e-waste on several health outcomes in children and adults from different research

Target systems/Reference	Exposure area	Exposed population	Health effects
(Leung et al., 2008)	E-waste recycling workshops,	Workers and residents	Dust: Hazard Quotient for Lead = 83; Workshop: Hazard Quotient for Lead = 402
(Wang et al., 2012)	Informal e-waste recycling area	Primary school children	Blood lead levels in three groups were recorded as 8.1 μg/dL, 7.0 μg/dL, and 2.8 μg/dL. The percentage of children with blood lead concentrations exceeding 10 μg/dL was 35%, 39%, and 0% for these groups, respectively. A negative correlation was observed between blood lead levels and IQ.
(Zheng et al., 2016)	Ecological: exposed area vs reference area	Children (n = 166)	The lead content in $PM_{2.5}$ was measured at 160 ng/m^3, while the corresponding hazard quotient for adults (HQadult) was calculated to be 0.012, and for children (HQchildren), it was 0.018.
(Gangwar et al., 2019	Ecological: exposed area vs reference area	Adult residents (n = 132)	Blood led levels were significantly different with values of 8.4, 0.9, and 0.4 μg/dL ($p<0.01$). Similarly, PM_{10} levels varied with values of 9.6, 9.3, and 3.3 μg/m^3. The prevalence of hypertension also showed significant differences with rates of 68%, 44%, and 32% ($p<0.001$). Notably, a positive correlation was observed between PM_{10} and systolic blood pressure (SBP) and diastolic blood pressure (DBP) ($p>0.05$).

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3.2.3 Multiple elemental exposures amongst workers at the Agbogbloshie electronic waste (e-waste) site in Ghana

As technology advances, so does the concern for the end-of-life disposal of electronics. In the current century, electronic waste has emerged as a global issue, particularly impacting developing nations. Ghana is home to one of the most environmentally unfriendly e-waste sites, Agbogbloshie. Once a marshy area in Accra, it has transformed into one of the most hazardous communities worldwide due to the unregulated dumping of electronic waste. Electronics contain various materials and chemicals, including rare metals, and manufacturers often incorporate non-environmentally friendly chemicals in their production processes. Exposure to these chemicals without proper protective measures can have adverse health effects.

In this section we will discuss the research work by Srigboh et al. (2016). Their study elucidated the impact of multiple chemicals on the well-being of workers and residents at the Agbogbloshie e-waste site. The primary goals of their research were to assess exposures to essential elements (copper, iron, manganese, selenium, zinc) and toxic elements (arsenic, cadmium, cobalt, chromium, mercury, nickel, lead) in the urine and blood of male workers and females. Additionally, they determined the median number of years worked at the site, categorizing four main working sectors: dealing, sorting, dismantling, and burning. The findings from their analysis revealed elevated levels of blood cadmium (median of 1.2 mg/L) and lead (6.4 mg/dL; with 67% exceeding the U.S. CDC/NIOSH reference level), as well as urinary arsenic (38.3 mg/L; 39% surpassing the U.S. ATSDR value) when compared to reference populations from other areas.

Table 4 Results from participants.

Participants	Working category	Age average	Result
Female (n=11)	Non-e-waste related	26.0	Differences in elemental biomarkers were observed when comparing female service workers and male e-waste workers. Median values for several studied elements, including blood Cd, Hg, Cu, Mn, Se, and urinary As, Co, Cr, Hg, Ni, Pb, Cu, Zn, were higher in females. Notably, urinary

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			Ni and Zn were significantly elevated among the female participants.
Male (n=58)	E-waste related	25.9	The average blood Pb level in males was more than twice that of females. In terms of urinary elements, the Kaiser-Meyer-Olkin (KMO) value was 0.74. The primary eigenvalue derived from the matrix represented 40.0% of the overall variability, while three eigenvalues collectively accounted for 66.7% of the total variance. A diagnostic analysis of the scatterplot revealed three distinct clusters of urinary elements: a) Zn, Cr, Pb, Co, Cu; b) Hg, Ni; and c) As. The duration of working in e-waste was positively correlated with blood Cu, Zn, Cd, Se, and Hg levels, as well as with urinary Ni and Pb.

3.3 Discussion

Electronic waste has evolved into a global concern, transcending the boundaries of Ghana to become a challenge for the entire world. According to the results and analysis, it was revealed that a significant portion of electrical appliances ending up at the Agbogbloshie e-waste site originates from developed nations like the United States of America and Western European countries. This practice has persisted for decades, with its peak chaos in the early 2000s when Ghana privatized most of its industries due to overborrowing without prudent utilization for their intended purposes, abandoning Nkrumah's plan of making the country Africa's most industrialized.

To address the electronic waste issues, developed nations should align their actions with their advocacy. It is recommended that they conduct thorough inspections of all electronics or electrical appliances at their ports before shipping to countries like Ghana. Leveraging their technological advancements, they can utilize modern scanners to identify outdated or obsolete appliances in containers before shipment. The associated costs can be shared between the government and the exporter, with strict penalties for offenders. Given the economic challenges in the country, where citizens often prefer secondhand products over new appliances, the legislation must be actively implemented. While a complete ban on secondhand electronics may not be

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feasible, port officials should cease corrupt practices of turning a blind eye to certain imported appliances, ensuring that legislation is enforced effectively.

Regarding legislation, given Ghana's affiliation with both the Basel and Bamako conventions, as well as their inclusion in our 1992 constitution, all regulations related to e-waste and waste in general should be strictly enforced, and violators should face consequences as previously mentioned. Prior to enforcement, a comprehensive public education campaign must be implemented to inform the public about the detrimental effects of e-waste on health and environmental contamination. Subsequently, individuals who violate these regulations can be penalized without the excuse of ignorance, as public awareness efforts will have eliminated any claims of being unaware of the potential harm or the existence of relevant laws.

Additionally, the government needs to develop the capacity to gather data on the categories of electrical appliances that become waste or are already obsolete upon arrival in the country. It is essential for the government to track the quantity of electronic waste entering Agbogbloshie and other e-waste centers. The compilation of this data could assist the government in addressing the electronic waste issue effectively, identifying the most common obsolete appliances that end up at the site, and determining their countries of origin. This information is crucial for establishing future regulations to address the challenges posed by e-waste.

In Ghana, it is widely known that those employed at the Agbogbloshie e-waste site contribute significantly to the development of Accra and the local economy. This became evident during a decongestion exercise when the youth working at the site lost their source of income. Since the Ghana Environmental Protection Agency (EPA) sells permits and the regional metropolitan levies daily and annual taxes on them, the government, or the ministry responsible for the environment could allocate some of the generated funds to establish a more sustainable recycling center. This initiative would not only create a more sustainable environment for e-waste recycling but also generate job opportunities for the youth, who would contribute to the development of the city by paying taxes.

Following the decongestion initiative orchestrated by the city's mayor, the land has remained tainted and polluted. While a section of the cleared area has been addressed, another portion remains uncleared and contaminated, now becoming occupied by criminals and drug

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dealers. Given the government's intentions to construct structures for future projects, thorough research and analysis are essential. The findings from this research can guide the selection of appropriate remediation methods to address leached chemicals in the soil, which have led to contamination of groundwater and nearby river bodies. Common remediation techniques include:

1. Phytoremediation involves utilizing plants to absorb and accumulate contaminants.

2. Bioremediation is a process utilizing microorganisms, including bacteria, fungi, or plants, to break down and neutralize pollutants or contaminants in the environment.

3. Soil washing is a remediation technique aimed at eliminating contaminants from soil through a physical separation process. This method employs water or other washing agents to extract and separate pollutants from the soil matrix. The procedure typically consists of the following steps:

a. Excavation: Contaminated soil is initially excavated and transported to the soil washing facility.

b. Screening: The soil undergoes screening to eliminate large debris and stones, ensuring a more consistent treatment.

c. Washing: Water or washing agents are then applied to the soil to facilitate the separation of contaminants. This step seeks to dissolve or suspend the contaminants, allowing them to be washed away from the soil particles.

d. Separation: The mixture of soil and washing solution is subjected to various physical separation techniques, such as gravity settling, flotation, or centrifugation. These methods aid in separating contaminants from the soil particles.

e. Treatment: The separated contaminants may undergo further treatment to neutralize or transform them into less harmful forms.

f. Reuse or Disposal: The cleaned soil can be reused in its original location or appropriately disposed of, depending on regulatory standards and the nature of the contaminants.

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Since the other part of the results and discussion delves into the health effects of e-waste on human health, I explored current health trends and other research dissertations discussing the impact of e-waste on human health. There is ample evidence demonstrating the adverse effects of unregulated e-waste sites on individuals residing and working within them, with these negative consequences extending to nearby communities. For instance, a notable case is exemplified by the research conducted by Steinhausen et al. in 2022, revealing that activities at the Agbogbloshie e-waste site have impacted the Korle Lagoon, resulting in the detection of heavy metal residues in fish from the lagoon. Continued consumption of fish from the lagoon can lead to diseases associated with e-waste.

E-waste sites exhibit variations in socioeconomic factors, environmental characteristics, and occupational activities, necessitating different approaches to preventing or finding solutions for each site. The Agbogbloshie e-waste site has been widely recognized and studied by local and foreign scholars, with most studies focusing on social aspects, environmental concerns, and health issues affecting residents.

Limited research has been conducted on the health impact of e-waste on Agbogbloshie's residents. Cases of elevated blood lead and cadmium levels in children from a Chinese e-waste recycling town (Zheng et al., 2008) and reports of elemental exposures among workers at the Agbogbloshie e-waste site in Ghana indicate a need for further investigation. The findings from various studies, including those presented in this thesis, suggest that workers in Agbogbloshie may face increased exposure to toxic elements.

A 2020 report by Amoabeng Nti et al. discusses particulate matter generated by the open burning of e-waste, contributing to air pollution within the community. Workers frequently involved in open waste burning are most likely to be affected. These studies, when compared to Zeng et al. in 2022, demonstrate consistency in their findings.

This research is based on an extensive review of multiple dissertations exploring the impact of electronic waste on individuals at the Agbogbloshie e-waste site. The primary focus during the initial review was on the effects of particulate matter within this e-waste site. The researchers aimed to establish a link between the concentrations of PM (2.5, 2.5–10, and 10 μm) in the breathing zone and the lung function of informal e-waste workers at Agbogbloshie.

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To assess the responses of lung function to PM (2.5, 2.5–10, and 10 μm), they conducted a longitudinal cohort study, revealing that particulate matter poses health risks to both residents and workers at the e-waste site. The air quality index at the waste site is unsuitable for both work and habitation, potentially leading to cancer, respiratory issues, neurological effects, and drug addiction among individuals who worked and lived at the waste site.

A report from Bloomberg on May 29, 2019, indicated the prevalence of various ailments, such as respiratory problems, chronic nausea, debilitating headaches, and skin diseases due to poor air quality and direct inhalation of toxic chemicals during the open burning of e-waste. These findings align with research by Zeng et al. in 2022, which examines an unregulated e-waste site in Guiyu, China.

Another significant topic explored is the impact of blood lead concentration in humans due to e-waste exposure. This was chosen for discussion because a considerable number of workers at the e-waste site may have lead in their blood, potentially leading to severe health implications. Research by Amankwaa et al. (2017) sheds light on how lead can enter the system during the dismantling and burning of electronic waste. The lack of protective gear for approximately 80-90% of e-waste workers makes them susceptible to lead exposure.

During their study, blood samples underwent analysis to determine lead levels, revealing that e-waste workers exhibited a wider range of higher blood lead levels compared to non-e-waste workers. Elevated blood lead levels are associated with adverse health effects, especially for children, making proper care crucial in dealing with e-waste recycling.

Another part of the study assessed the impact of exposure to multiple elements among workers at the Agbogbloshie e-waste site, conducted by Srigboh et al. (2016). Their analysis revealed that workers engaged in burning e-waste appeared to have the highest biomarker levels, indicating exposure to various toxic elements at concerning levels.

These findings contribute to the growing body of research at Agbogbloshie and other similar sites, emphasizing that individuals working in e-waste environments are exposed to various toxic elements. A report from Ghana Web on September 8, 2023, highlighted Agbogbloshie as one of the most polluted areas in Ghana, with an air quality index far exceeding international standards.

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3.4 Study limitation

Obtaining up-to-date data on specific research topics can be quite challenging in Ghana. There seems to be a lack of emphasis on record-keeping and data collection regarding important matters. Consequently, when the need arises for solutions, there is often a lack of readily available data to address the issues effectively.

In my quest to find medical data about the health and environmental effects of e-waste on the official Ministry of Health and the ministry of land and environment website, I encountered difficulties. Such data could serve as an educational resource for the public, shedding light on the gradual health hazards posed by e-waste.

Additionally, I faced obstacles when attempting to secure interviews with certain professionals. In Ghana, it appears that individuals in particular positions tend to avoid discussing specific issues like this, and such matters are not prioritized as they should be.

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4. RECOMMENDATIONS AND CONCLUSIONS

Based on the findings presented in this thesis, I strongly recommend that the government of Ghana take decisive and practical steps to establish and maintain a sustainable e-waste recycling center. It is imperative to implement a comprehensive approach to address the existing challenges effectively.

1. **Enhanced Entry Point Scrutiny:** The government should institute rigorous monitoring and scrutiny at the entry points where electronic waste materials enter the country. This will help regulate and control the inflow of such materials.

2. **Strengthened Importation Laws:** The laws governing the importation of electronic materials must be reinforced and rigorously enforced to ensure compliance. This will serve as a deterrent to improper disposal practices.

3. **Site Transformation:** Given the current state of the e-waste site, which is marred by piles of waste materials and social issues, I recommend the government undertake a comprehensive transformation. This could involve constructing a more sustainable e-waste recycling facility. Such a facility should adhere to established regulations and guidelines for environmentally responsible waste management. But before that there site should be investigated by the government and based on the results an appropriate remediation method should be used to remediate the site to avoid further contamination. Also, the nearby river and lagoons should also be treated after investigation or conducting research on them.

4. **Material Recovery Facility:** Many interviewees strongly advocated for the establishment of a state-of-the-art, sustainable material recovery facility. Their plea was for the government to create this facility, which should be connected to a vocational center. This linkage would provide them with the opportunity to acquire skills for personal livelihoods, enabling them to earn income independently. Building a material recovery facility on-site would be beneficial. This facility can extract valuable metals from discarded gadgets for reuse in various applications. This not only reduces waste but also contributes to resource conservation.

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5. **Data Collection:** To inform future research efforts and policymaking, it is essential to accurately document and input data related to the volume and types of e-waste generated.

6. **Worker Training and Equipment:** E-waste workers should receive proper training and be equipped with appropriate gear to ensure their safety and health. This includes protective equipment to mitigate the risks associated with handling electronic waste.

By implementing these recommendations, the government can not only address the current environmental and social challenges associated with e-waste but also create a sustainable, revenue-generating solution. Furthermore, these measures can help alleviate the unemployment crisis, promote responsible waste management, and contribute to a healthier environment for all.

4.1 Conclusion

The increasing global concern over electronic waste is a consequence of its widespread integration into daily life and rapid technological expansion. This dissertation has underscored the significant adverse environmental impacts resulting from e-waste, particularly evident in illicit sites like Agbogbloshie. Common traits in social demographics and operational repercussions are shared among these sites. In Agbogbloshie, recognized as one of the world's most polluted e-waste sites, open burning during peak operations caused severe environmental damage, including air pollution, the release of harmful particulate matter, and the dispersal of various chemicals.

E-waste is accountable for a spectrum of health issues, ranging from skin diseases and respiratory problems to elevated lead levels in the blood and cancer. Additionally, apart from health concerns, e-waste contaminates the environment, especially when waste piles up, leading to chemical leachates affecting the ground and groundwater during rainfall.

To foster the development of Ghana and Agbogbloshie, the government could adopt the 3S method proposed by Lavagnolo & Grossule (2018). This method revolves around three equal pillars of 'S': Sanitization, Subsistence economy, and Sustainable landfilling. Sanitization focuses on improving living standards by ensuring consistent waste collection. Allocating waste bins strategically and ensuring regular collection, backed by community engagement, can alleviate waste-related health issues.

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The second 'S,' Subsistence Economy, emphasizes the economic contribution of e-waste. Supporting waste pickers through employment or sponsorships can motivate them and positively impact the country's economy. The final 'S,' Sustainable Landfilling, advocates for well-engineered landfills, challenging the common practice of open dumping in Ghana. The final 3S method recommends substantial investment in creating sustainable landfills to address the waste management crisis effectively.

By following these processes, Ghana could witness a transformation in its waste management system, fostering significant improvements in the waste sector. Implementing these measures could contribute to realizing the dream envisioned by Osagyefo Kwame Nkrumah for Agbogbloshie.

Ultimately, in addition to the Ghanaian government fulfilling its responsibilities, Western nations, which establish rules and legislation governing e-waste, must also play their part. It is crucial to ensure thorough scrutiny of every electrical appliance shipped to developed countries, aiming to prevent e-waste problems. Stringent penalties should be imposed on offenders. Fines collected from violators could fund public educational programs, particularly targeting individuals, including citizens of developing countries in the diaspora, who export electrical appliances without proper checks in the pursuit of profit. They need to comprehend the harm they inflict on their countries and the potential legal consequences.

Moreover, environmental associations can sponsor research initiatives to investigate e-waste sites, assess contamination levels, and aid in land remediation. Educational efforts should encourage these communities to embrace the principles of the circular economy associated with e-waste and waste in general, offering financial benefits. Collaborative programs could establish material recovery centers where youth can acquire skills in extracting valuable materials from discarded e-waste. Certain components, like motherboards, could be reused or refurbished for other electronics. Developing these skills could motivate young individuals to establish their enterprises, potentially discouraging risky endeavors such as crossing the Mediterranean Sea in search of better living conditions and income. Acting today can prevent Western citizens' taxpayer money from being used when leaders of developing countries seek funds, which may not be used for their intended purposes.

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