Working paper

International Growth Centre

Recyclers at risk?

Analysis of e-waste livelihoods and blood lead levels at Ghana's recycling hub, Agbogbloshie

Ebenezer Forkuo Amankwaa
Alexander K.A. Tsikudo
John Bowman

October 2016

When citing this paper, please use the title and the following reference number:
E-33113-GHA-1

DIRECTED BY LSE UNIVERSITY OF OXFORD

FUNDED BY UKaid from the British people

Recyclers at risk? Analysis of e-waste livelihoods and blood lead levels at Ghana's recycling hub, Agbogbloshie

Authors

Ebenezer Forkuo Amankwaa

Alexander K.A. Tsikudo

John Bowman

With support from

Louis K. Frimpong

Onallia E. Osei

Christine Asedo

Acknowledgment

The authors are grateful to the International Growth Centre (IGC), LSE for the grant support for this research project. We are also indebted to the e-waste workers and traders at the Agbogbloshie e-waste site, and all others who made this research possible. We express our special gratitude to Dr. Henry Telli for his advice and coordination, and the two reviewers for their constructive comments that advanced the argument and contribution of this report.

Correspondence

Ebenezer F. Amankwaa; ebenchief@yahoo.com

Table of Content

List of Figures

List of Tables

Acronyms

AAS	Atomic Absorption Spectrometer
ABLES	Adult Blood Lead Epidemiology and Surveillance
ASDA	Agbogbloshie Scrap Dealers Association
BAN	Basel Action Network
BFRs	Brominated Flame Retardants
BLLs	Blood Lead Levels
CBD	Central Business District
CDC	Centers for Disease Control
CRTs	Cathode Ray Tubes
EDTA	Ethylene Diamine Tetraacetic Acid
EEE	Electrical and Electronic Equipment
EPA	Environmental Protection Agency
FGDs	Focus Group Discussions
GAEC	Ghana Atomic Energy Commission
GIS	Geographic Information System
GPS	Global Positioning System
GreenAd	Green Advocacy
IQ	Intelligence Quotient
LCD	Liquid Crystal Display
MESTI	Ministry of Environment, Science, Technology, and Innovation
MoH	Ministry of Health
MoTI	Ministry of Trade and Industry
NGOs	Non-Governmental Organizations
NYA	National Youth Authority
ODK	Open Data Kits
OECD	Organisation for Economic Co-operation and Development
PAHs	Polycyclic Aromatic Hydrocarbons
PBDE	Polybrominated Diphenyl Ether
PCBs	Polychlorinated Biphenyls
QoL	Quality of Life
TEs	Trace Elements
USEPA	United States Environmental Protection Agency

Overview

Every epoch has its developmental ethos. The present era features rapid growth in informality, intense globalization, and technological advancements. The interplay of these processes generates various forms of spatiality which are scaled and continuously reproduced with time. Whereas these are manifest evolution of capitalism spearheaded by advanced capitalist countries, its material legacies, including discarded electrical and electronic waste (popularly called e-waste) creates significant management challenges in most developing countries. Other concerns related to the transhipment of e-waste include environmental and health risks which emanate from poor end-of-life disposal techniques. Despite the health implications of improper recycling deployed by informal workers, e-waste materials have become key sources of survival and livelihood for some urban residents whose chances for a formal sector employment seems a well-nigh possibility. As a result, e-waste presents opportunities to eke a living and unleash their entrepreneurial ingenuity. In Ghana, Agbogbloshie is the focal point for such complex processes. This study seeks to unravel these complexities. It was inspired by three central motives. First, theorize the complexity of e-waste and the informal recycling economy in Agbogbloshie. Second, investigate the health risks, particularly lead poisoning, associated with e-waste recycling. Third, proffer mitigative and innovative solutions to find a middle ground for the livelihood-health nexus in Agbogbloshie.

The motivations are underpinned by the claim that e-waste recycling appears lucrative yet embedded with significant health risks. The interplay of these benefit-risk binaries is essential to hypothesize the future sustainability of the rapidly growing e-waste sector and its relevance to poverty reduction. The study affirms this possibility and illustrates that the daily average income for e-waste workers in Agbogbloshie appears higher than the national daily minimum wage. For example, collectors who occupy the lowest segment in the e-waste economy earn GH¢ 25 which is over four times the income of an average public servant[1]. The study also found increasing blood lead levels among both e-waste and non e-waste workers on the site. While this seems to undermine the short term economic gains, it does not constitute an immediate concern for recyclers. Thus, the implications of these findings are significant in formulating policies that regulate and manage e-waste in Ghana.

[1] At the time of the study, the daily minimum wage was pegged at GH¢6 from the previous GH¢5.24. http://citifmonline.com/2014/05/01/minimum-wage-pegged-at-ghc-6/

1.0 Background

Rapid urbanization, coupled with poor infrastructure, and inadequate formal job opportunities in developing countries is spurring new social-urban dynamics, environmental challenges, and an accelerated expansion of the informal economy (Amankwaa, 2013). In Ghana, the growth of the informal sector is linked to e-waste recycling (Oteng-Ababio et al., 2014a). E-waste entails various forms of old electrical and electronic equipment (EEE) that no longer have any value to their possessors (Tiwari and Dhawan 2014), as well as discarded or broken electronic devices that enter the waste stream. These various forms of e-waste are subsequently appropriated as reused, resold, salvaged or disposed. However, management of e-waste with respect to disposal, recycling or reselling has grown from being a local or national issue to the global scale.

E-waste is the fastest growing segment of the overall waste stream in the world; due to both the transshipment of used materials from the developed world to the developing world as well as increased disposal within poor countries (Lepawsky, 2012). For some scholars, the increased dumping of materials like mobile phones, refrigerators, and computers (including laptops) are driven by capitalist consumption, and grounded in the need to bridge the perceived digital divide between the developed and developing world (Grant and Oteng-Ababio, 2012; Pickren, 2014). Many scholars argue that these discarded EEE materials pose health and environmental hazards to the poor, while others argue that the products constitute forms of opportunities and means of survival for those who work in the informal markets (Oteng-Ababio et al., 2014a). This framing capture the scholarship on e-waste within which value, waste, and risk are discursively postulated to be at odds with each other (Moore, 2012). However, while this framing streamlines the debate into an either/or situation, it invariably elides the conditions of possibility which are enacted by people involved in collecting and working with e-waste. The linearity of thought in which EEE products are perceived to conform to a spectrum of value and waste—without any possibilities for reworking or refurbishment—has now been challenged (Lepawsky and Mather, 2011; Oteng-Ababio and Amankwaa, 2014). Studies by Grant and Oteng-Ababio (2012) and Moore (2012) suggest going beyond the discursive framework of value and waste.

Keeping these debates in mind, the e-waste phenomenon has undeniably become a major challenge for developing societies due to inadequate infrastructure and non-existent regulatory frameworks. The contrasting conceptions of e-waste and its associated markets

make studies related to the subject politically charged (Moore, 2008). Geographers, political ecologists, and environmental historians are among several scholars spearheading research on e-waste and its material importance (Castree and Braun, 2001; Gidwani, 2008; Moore, 2012). From studies that aims at unraveling the political reproduction of marginality (Moore, 2008), to those focused on challenging linearity of thought (Lepawsky and Mather, 2011), scholars have deployed the notions of waste and e-waste in particular to examine social and environmental justice (Paulido, 2000), environmental abjection (Moore, 2008), urban dynamics (Grant and Oteng-Ababio, 2012), and the contestations that the concept of waste invokes. To this extent, the issue of e-waste is consistent with debates and interests that concepts such as nature embodies (Adovor Tsikudo, 2016, forthcoming).

The current study builds on the scholarships discussed above. We start with the complex political economy of e-waste recycling as illustrated by Grant and Oteng-Ababio's (2012) work in Agbogbloshie; and our work builds on their efforts by providing the necessary empirics which seeks to substantiate the actual health risks of e-waste workers.

Our work was motivated by three primary questions:

- What are the key livelihood activities for workers within Agbogbloshie and what changes would the e-waste recyclers desire?
- To what extent is e-waste recycling a matter of concern for workers' blood lead levels (BLLs)?
- And if e-waste recycling is found to have adverse effects on BLL, what innovative solutions are available that have a high potential for success as Agbogbloshie currently exists?

We approached these questions using mixed-method techniques, including participatory community asset mapping, in-depth interviews, focus group discussions (FGDs), and laboratory analysis of human blood samples. The research site is the e-waste recycling and dumpsite at Agbogbloshie.

Our work challenges the argument that the primary forces behind e-waste stockpiles in Ghana are the marginalized individuals who work in the recycling sector. While sympathetic to the interconnections of work in this sector to the wider economy, we also assert that in Ghana, political will, poor regulatory frameworks, and non-existent municipal waste management infrastructure are the most important causes of the mounting stockpiles of e-waste in the country. We make this argument by interweaving the general literature on waste (e-waste) in political ecology, urban geography, and environmental justice.

2.0 Moving beyond the livelihood vs. health divide

2.1 The e-waste continuum

Collectively called e-waste, the generation, shipment, and dumping of EEE materials such as computers, mobile phones, and refrigerators between developed and developing countries has increased with globalization. The digital revolution has triggered increased consumption, and disposal, of EEE and consequently, increased disposal underpins new urban dynamics in most developing countries. Particularly, this has become a major challenge to city managers, as well as to environmental justice scholars, urban geographers, and political ecologists (Pulido, 2000; Moore, 2012; Pickren, 2014). Put forward as one of the foremost expressions of material connection between developed and developing countries, the issue of e-waste has increasingly become the focus of debates surrounding environmental justice and economic survival strategies over the past two decades (Moore, 2012). Despite several conventions and international frameworks to regulate movement from developed to developing countries, e-waste stockpiling continues unabated (cf. Basel, 2010).

Thus far, the e-waste debate has been framed in the Manichean language of good vs evil. Proponents assert that EEE export, comprising computer parts, laptops, and mobile phones from developed countries help address the technological deficit in developing countries. Furthermore, these scholars stress that several EEE materials contain valuable substances such as gold, copper, and aluminium, which can be retrieved and recycled for reuse. Conversely, critics contend that these materials are harmful to destination countries because they contain hazardous compounds such as mercury, lead, cadmium, and flame retardants which are detrimental to both human health and the environment.

Because these two schools of thought reduce the highly complex e-waste economy to an either/or dichotomy, they have neglected the issues of contingency and agency. The works of Lepawsky and Marther (2011) challenge the mental framework that limits the argument to an axis of value and waste. Lepawsky and Marther argue that the debate has stressed that developed countries tend to be places of value, while developing countries become dumping grounds. According to Lepawsky and Marther (2011), such linearity of thought constrains how e-waste materials are treated at receiving destinations. The authors use the cases of Bangladesh and Canada to assess how e-waste shipments are treated in destination areas, showing great ingenuity and wealth created in the reworking markets – as well as the potentials for substantial human and environmental damage.

Other scholars, including Grant and Oteng-Ababio use a political economy approach to represent the multifarious and structured markets in Ghana's e-waste recycling hub, Agbogbloshie. They note significant material and monetary links between the formal and the informal economy. Although e-waste recycling seems to be mainly undertaken by informal workers, recovered materials are resold back to formal manufacturing firms as raw materials. These linkages challenge the conventional idea that the journey of e-waste terminates at dumpsites in China (Guiyu), India (Bangladesh), and Ghana (Agbogbloshie).

Our work follows Grant and Oteng-Ababio's and confirms that there is rarely 'pure waste'(Cf. Moore, 2012). Rather, materials recovered through recycling constitute sources of survival and raw material for firms. While being considered risky, the e-waste industry remains a lucrative business attracting all manner of people who use rudimentary tools and deploy high ingenuity to eke a living. For Grant and Oteng-Ababio (2012), the economic value of the e-waste industry cannot be underestimated. Globally, the value of the industry exceeds seven billion dollars (Grant and Oteng-Ababio 2012).

This notwithstanding, the appeal of quick money and non-existent regulatory frameworks forces an examination of associated issues such as worker and resident health, and environmental pollution. The foregoing confirms Sarah Moore's (2012) claim of the materiality of waste. The material basis of e-waste is considered a generative argument as it requires continuous analysis with specific regards to how, why, and whom such materiality matters.

2.2 The health link

E-waste contains multiple toxic chemicals such as brominated flame retardants (BFRs) and polychlorinated biphenyls (PCBs), and toxic metals including lead (Pb), cadmium (Cd), and platinum (Pt). There are some specific hazardous components such as cathode ray tubes (CRTs), liquid crystal display (LCD) screens, batteries, circuit boards, and plastics that are found within consumer electronics. While these chemical compounds are naturally occurring, hydrophobic substances (which are not soluble in water) they tend to be released during recycling. For example, lead compounds are used within popular components and is considered one of the major heavy metal contaminants found during recycling. Table 2.1 summarises some of the known hazards associated with poor e-waste recycling.

Generally, workers are exposed through three different routes: *inhalation*, *skin contact* or *ingestion* (Grant et al., 2013). Amankwaa (2014a) further indicates that vulnerable

populations such as children, pregnant women, and elderly people within the families of e-waste recycling workers stand to suffer take-home contamination from workers' clothes and skin or even direct high-level contact/exposure.

Table 2.1: Environmental health hazards associated with poor e-waste management practices

E-waste component	**Processes**	**Potential Occupational Hazard**	**Potential Environmental Hazard**
Cathode ray tubes	Breaking, removal of copper yoke and dumping	Silicosis. Cuts from CRT glass. Inhalation or contact with phosphor containing cadmium or other metals	Lead, barium and other heavy metals leaching into ground and release of toxic phosphor
Printed circuit boards	Desoldering and removing computer chips	Tin and lead inhalation. Possible brominated dioxin, beryllium, cadmium and mercury inhalation	Air emission of the same substances
Dismantled printed circuit board processing	Open burning of waste boards	Toxicity of workers and nearby residents from tin, lead, brominated dioxin, beryllium, cadmium and mercury inhalation	Tin and lead contamination of immediate environment, including surface and ground waters, brominated toxins, beryllium, cadmium and mercury inhalation
Chips and other gold plated compounds	Chemical stripping using nitric and hydrochloric acid along river banks	Acid contact with eyes, skin may result in permanent injury. Inhalation of mists and fumes of acids, chlorine and sulfur dioxide gases can cause respiratory irritation to severe effects (pulmonary edema, circulatory failure and death)	Hydrocarbons, heavy metals, brominated substances etc. discharged directly into river and banks. Acidifies the river destroying fish and flora
Plastics from the computer and peripherals	Shredding and low-temperature melting	Probably hydrocarbon, and brominated dioxin exposure to workers living in the burning works area	Emission of brominated dioxins and heavy metals and hydrocarbons
Secondary steel or copper and precious metal smelting	Furnace recovers steel or copper from waste	Exposure to dioxins and heavy metals	Emission of dioxins and heavy metals
Wires	Open burning to recover copper	Brominated and chlorinated dioxin and polycyclic aromatic hydrocarbons (PAHs) exposure to workers in the burning area	Hydrocarbon and ashes, including PAHs discharged into air, water and soil

Source: Pinto, 2008.

Most importantly, exposure to these substances particularly Pb, Cd, and dioxins has been associated with increased incidence of chronic diseases later in life: including obesity, type 2 diabetes, hypertension, lung cancer, and cardiovascular diseases (Korrick et al., 1999;

Everett et al., 2011). Also, Pb, and Cd have strong neurodevelopmental and neurobehavioural effects, decreased intelligence (as measured by intelligence quotient - IQ), and impaired cognitive functioning, especially in children (Surkan et al., 2007). Similarly, lead exposure, combined with genetic predisposition, can trigger schizophrenia and possibly lead to the development of the neurodegenerative diseases such as Parkinson (Weisskopf et al., 2010).

Many concerns have been raised about the health implications of e-waste recycling in Agbogbloshie, but little research exists to attest to the veracity of the claims. For instance, the pioneering work by Brigden et al. (2008) which garnered international attention around e-waste activities in Agbogbloshie only referenced earlier reports for e-waste open burning sites in China. The authors reported that, certain metals were present at concentrations over 100 times the world permissible standards but did not attempt to quantify damage caused to the environment or off-site human health. A similar study by Caravanos et al. (2011), which assessed workers and environmental chemical exposure risks at Agbogbloshie revealed elevated levels of heavy metals through personal air samples collected from workers and their immediate environment. The study found extensive lead contamination in both ambient air and topsoil but was inconclusive on the potential human health impact.

Asante et al's (2012) study which sought to understand human contamination by multi-trace elements (TEs) at Agbogbloshie found that concentrations of Pb in urine of recycling workers were significantly higher than those of reference sites. In a recent study to ascertain the presence of polybrominated diphenyl ether (PBDE) in the growing of vegetables in Agbogbloshie, Oteng-Ababio et al. (2014b) discovered massive contamination of five traces, but were unable to determine how they impact consumers. Given this difficulty, this study goes one step further by examining the health risk of workers in relation to lead contamination. Other research works elsewhere have established that e-waste recycling can result in elevated BLLs (Huo et al., 2007; Liu et al., 2011).

3.0 Study Area and Research Methodology

3.1 The Ghanaian context

Ghana is a signatory of the Basel Convention: the international instrument that controls the transboundary movements of hazardous waste, including e-waste, and prohibits trade between Annex VII countries (OECD, EU and Liechtenstein) and non-Annex VII countries. However, the Ghanaian government is yet to ratify the convention, which

compromises its applicability (Oteng-Ababio and Amankwaa, 2014, p. 190). Although there is dearth of official data on the generation of EEE in Ghana, an estimated 215,000 tons were imported in 2009, comprising 30 percent (64,000 tons) new products and 70 percent (147,000 tons) second-hand items (Amoyaw-Osei et al., 2011). Also, 40 to 60 percent of domestically generated e-waste is recycled, out of which 95 percent is done informally (Oteng-Ababio and Amankwaa, 2014, p. 182). From these statistics, as well as the lived experience of workers within the recycling sector, Agbogbloshie is the heart of e-waste recycling in Ghana.

Effective policies to protect e-waste workers, their families and those that live in and around Agbogbloshie require empirical knowledge of the risks found in and around the site. This is against the backdrop of legislative gaps and lax customs control, which provide opportunities for the illicit entry of e-waste into the country. There is currently no specific legislation to regulate EEE disposal – except some loose environmental legislations which only incorporates sections on 'hazardous waste management and handling' (see EPA Act, 1994; Environmental Sanitation Policy of Ghana, 1999). Also, the key legislative principles which could impact sustainable e-waste management are vaguely defined, which compromises their enforcements. The limits to legal enforcement are compounded because the informal market is not captured under any other regulatory framework.

3.2 The Agbogbloshie setting

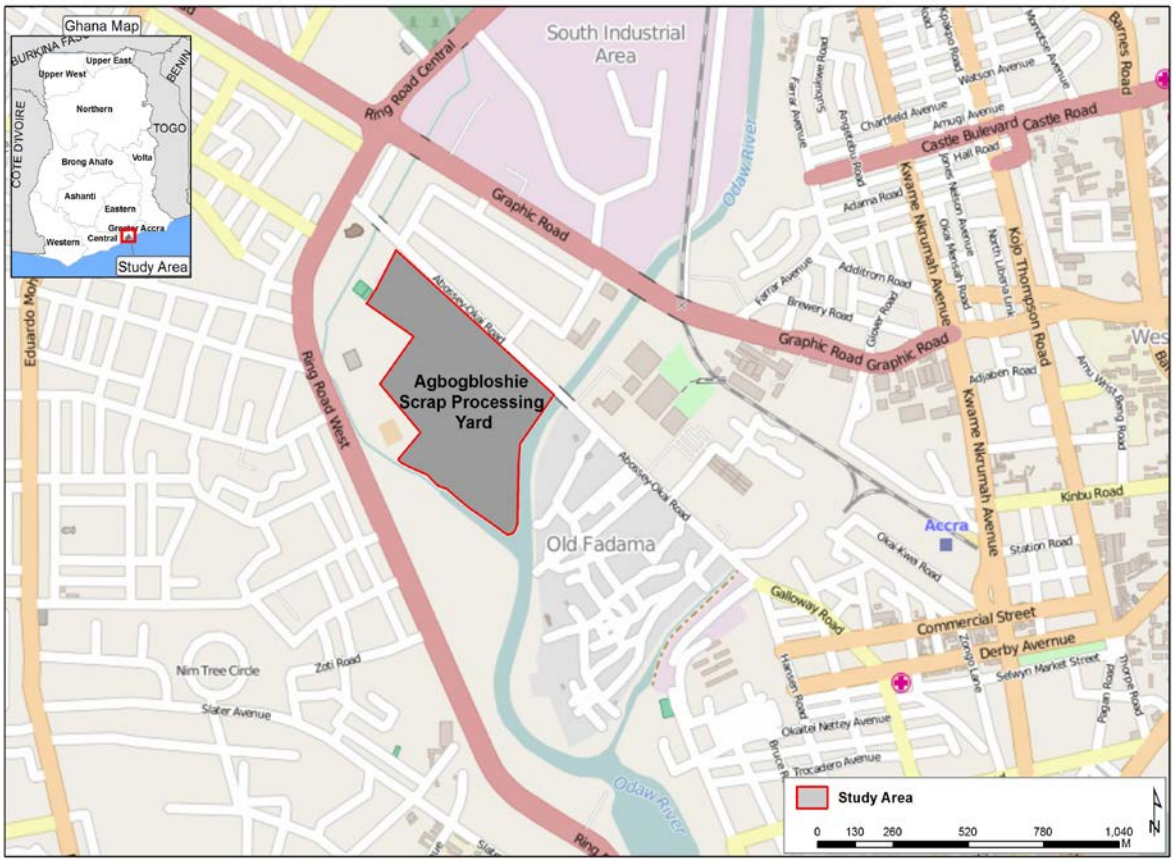
Agbogbloshie occupies 31.3 hectares of land along the banks of the Odaw River and Korle Lagoon, situated northwest of Accra's central business district (CBD) (see Figure 3.1). According to the 2010 Population and Housing Census, the population of Agbogbloshie is 8,305 (54 percent female and 46 percent male) (GSS, 2012). However, an enumeration exercise conducted by Housing the Massses in 2009 puts the population of Old Fadama[2] (generally referred to as Agbogbloshie) at 79,684 with a density of 2424.18 persons per hectare (People's Dialogue, 2010). Irrespective of these estimates, a visit demonstrates that Agbogbloshie is a densely settled, 'resource-poor' area with the majority of residents lacking access to basic services such as clean water and sanitation. Residential dwellings are a mix of concrete structures and wooden shacks.

[2] Old Fadama is a suburb of Accra made up of five Enumeration Areas defined by the Ghana Statistical Service in 2010 as: 'Efo Market' (0304303143), 'Presbyterian Church' (0304303139), 'Happy Corner Spot' (0304303140), 'H/No. Blk 12' (0304303142), and '31st December Market' (0304303138). There are 1,731 EAs in the Accra metropolitan area (AMA), which is the largest district within the Greater Accra region

The Agbogbloshie land belongs to the National Youth Authority (NYA), though it has been leased to the Agbogbloshie Scrap Dealers Association (ASDA), a self-generated organisation that helps protect the interests of e-waste workers. Originally intended for youth activities and sports fields, it was occupied in the 1980s together with the adjacent slum neighbourhood of Old Fadama by people from the Northern Regions of Ghana (COHRE, 2004; see also Amankwaa, 2013 p. 556).

Agbogbloshie is also home to Ghana's largest commercial fresh produce market, which attracts traders from all over the country, as well as seasonal migrants who engage in trade or the transportation of goods for clients in the congested market area. The presence of two major transport terminals within Makola Number 1 and Yam Markets easily connects Agbogbloshie to the rest of Accra and Northern Ghana. Finally, Agbogbloshie has generated international attention for its large e-waste processing site (Brigden et al., 2008). The site has been in existence for more than two decades, and e-waste recycling forms a subset of larger non-electronic scrap management activities. There are about 3,000 workers at the scrap yard out of whom 1,500 are registered members of ASDA.

Figure 3.1: Map of Agbogbloshie



Source: Authors construct, 2014

3.3 Methodology

The field work for this study was conducted at Agbogbloshie using the triangulation approach. It adopted the following techniques: a participatory community asset mapping using the Open Data Kits (ODK); focus group discussions (FGDs) with ASDA executives and e-waste workers; and expert interviews with policy makers and a selected NGO; and finally the collection of blood samples and workers biographical data for BLL analysis. Also, references were made to articles, books, and (un)published reports.

3.3.1 Participatory community asset-based mapping

The complexity of work in Agbogbloshie scrap yard was investigated through participatory community asset mapping. This was accomplished using hand-held global positioning system (GPS) devices and secured electronic forms designed with Open Data Kits (ODK). The design of the forms was derived from our broad research questions. This process allowed us to collect data on the social and physical infrastructure assets including, housing, access routes, work sheds, storage, toilets, and water. We also collected data on areas of trading, and other standards of the e-waste sector.

The approach entails identifying the strengths and capabilities of the community through their own participation. This ensured that workers saw themselves as collaborators in the research instead of being the research subjects. This helped us to understand the daily work patterns, forms of work, and the linkages of the scrap yard to the urban economy. The ultimate goal is to ascertain possible changes that the workers desire for themselves rather than presuming their work to be defined from an outside needs/deficiencies perspective as this will enable us formulate relevant policy recommendations.

Preliminary fieldwork commenced with three separate meetings with the recyclers. The first meeting was with ASDA executives to collectively brainstorm and list on-site community assets. This meeting also identified pertinent workers' concerns related to their work and health. Afterward, a training session on community asset mapping was offered to six nominated assistants from the various e-waste workers categories (collectors, dismantlers, refurbishers/repairers, burners, middlemen and dealers).

Overall, the community asset mapping took three days; each day was dedicated to two separate themes. Data on each of the themes identified were collected by the community asset mappers in collaboration with our research team. The community assistants possessed in-depth knowledge of the nooks and crannies of the yard, and facilitated easy access and

mobility within the site. Their guidance and all-clear signal was essential as recyclers within Agbogbloshie have grown suspicious of outsiders within their work space.

In all, we mapped 64 assets[3] on the basis of the various themes; physical (4), social (14), economic (42), and cultural (4). In the end, we collected data satisfactory to our team and the community. The results of this helped to generate site maps (of both assets and livelihood strategies) to explain the various existing categories of work at the yard and how these categories interconnect.

3.3.2 Focus group discussions and expert interviews

As part of the participatory approach, two focus group discussions (FGDs) were conducted: 1) eight workers comprising workers of the various e-waste work categories-collectors, dismantlers, burners/recyclers, repairers, middlemen, and scrap dealers; and 2) four executives of the local association (ASDA). With the objective of achieving a balanced perspective, a purposive sampling technique[4] was employed to select officials from government ministries and their related agencies responsible for the e-waste trade and/or management for in-depth interviews. These included; Ministries of Environment, Science, Technology, and Innovation (MESTI); Health (MoH); Trade and Industry (MoTI); and the Environmental Protection Agency (EPA); National Youth Authority (NYA); as well as an NGO, Green Advocacy (GreenAd). The interview instruments were open-ended and covered themes including the magnitude of the trade, their appreciation of e-waste recycling, available legislation (if any), and policy options for e-waste management. Personal observations, FGDs, and responses to the interviews were organized into themes for the analysis.

3.3.3 Blood collection, digestion and analysis

Blood samples were collected and analysed to evaluate the level of human exposure to lead. To ensure the absence of selection bias the multi-stage cluster sampling technique was employed. The first step involved a stratification to distinguish the various e-waste clusters for each stratum. Six clusters were identified within the chain of e-waste activities: collectors, dismantlers, recyclers, refurbishers/repairers, middlemen, and scrap dealers; and five clusters within the category of e-waste related activities: food vendors, water vendors, beverage vendors, petty traders, and others (e.g. drivers). This strategy was selected because variations in the population are within the clusters and not between them; each cluster has its own

[3] Conveniently classified with several overlaps

[4] A non-probabilistic sampling technique based on a certain purpose in mind

peculiar dynamics (procedure of entry, start-up capital, networking, etc). Quota sampling was then applied to the identified clusters depending on the intensity of the impact of e-waste activities and the concentration of population within the clusters. The sample size for each stratum was determined with the help of ASDA executives who estimated the population size of the different work categories. Thereafter, random sampling was employed to selected donors in each stratum. The same method was employed for the selection of donors from the non e-waste activities category, while those in the control group were randomly selected.

In all, one hundred and fourteen (114) blood donors were sampled, eighty-one (81) from the various clusters of e-waste workers, comprising 8 collectors, 28 dismantlers, 3 refurbishers/repairers, 8 recyclers/burners, 25 scrap dealers and 9 middlemen; and 33 from e-waste related activities; 20 chop bar operators and food vendors, 2 water vendors, 4 beverage sellers, 4 petty traders (clothing, footwear), 2 onion traders, and 1 driver. Out of the 114 donors, 83 were males and 31 were females. In addition, we used 14 people with no obvious direct relation to e-waste as a control group. They were chosen from amongst workers in the University of Ghana whose engagement is primarily office work. They were conveniently sampled because of the difficulty in getting donors from nearby residential areas where the population, lifestyle, and socioeconomic status are comparable to those of Agbogbloshie (Huo 2007; Guo 2014; Amankwaa 2014a).

After a written consent was sought from each volunteer, about 3 ml of blood was obtained from each donor (at the office of ASDA located on the site) with the assistance of a laboratory technician from the University of Ghana Hospital. The samples were collected in 5ml polypropylene tubes containing K3 EDTA as anticoagulant. The blood samples were transported to the Ghana Atomic Energy Commission (GAEC) laboratory in Accra for digestion and analysis. Upon arrival in the laboratory, they were immediately refrigerated at 4^{o}C until pretreatment.

During the digestion process, two (2) grams each of whole blood sample was weighed into Teflon beakers and 6ml of concentrated HNO_3 (65 percent) and 1ml of concentrated H_20_2 (35 percent) were added. The Teflon beakers were placed in caskets and put into an Ethos 900 microwave digester and allowed to digest for 20 minutes (see Milestone Acid Digestion Cookbook, Update January 1st 1996). Subsequently, the inner sides of the Teflon beakers were washed with distilled water and made to a final volume of 20 mL and transferred into pre-condition test tubes. The digested sample solutions were then assayed for lead using VARIAN AA-240FS Atomic Absorption Spectrometer (AAS).

The main parameters employed for the determination are presented in Table 3.1. For quality assurance and quality control purposes, reagent blanks and certified reference blood obtained from the International Atomic Energy Agency 452 (IAEA, 2011) of known composition were analysed using the same method with each batch of samples to ensure accuracy and to detect any contamination during the analytical procedure.

Table 3.1: Instrument parameters for AAS analysis

Element	Wave length (nm)	Slit width (nm)	Lamp current (mA)	Support	Fuel
Pb	217.0	1.0	5	Air	Acetylene

Source: Varian Analytical Methods, (1989).

Recoveries on IAEA 452 ranged 108.3 ± 21.86. All the digested samples were analysed at least three times, and typically, precision was less than 5 percent for all elements (see Table 3.2). The BLLs were expressed in micrograms per deciliter (1 μg/dL = 0.0484 μmol/L).

Table 3.2: Comparison of values and percentage recovery for standard reference material

Analyte	Measured value (μg/g) ± S.D	Certified value (μg/g) ± S.D	Recovery (%) ± S.D
Pb	2.6 ± 0.2	2.4 ±0.3	108.3 ± 21.86

Source: IAEA 452, 2011 and Field work, 2012

3.3.4 Statistical analyses

We performed statistical analyses using SPSS (version 16). We used independent sample *t*-tests or covariance analyses for comparisons of mean, chi-square analyses for test of frequency data, and linear regression analysis for the possible association between BLLs and influential factors. Differences were considered significant with a *p*-value < 0.05 and 0.01. The BLL results were compared with US Centers for Disease Control's (CDC) (1991; 2009) standards for lead levels to ensure consistency with the literature.

3.4 Ethical Considerations

Before contacting our research collaborators, the study was approved in writing by the Institutional Review Board (IRB) of the Noguchi Memorial Institute for Medical Research at the University of Ghana. The study was carried out in compliance with IRB conditions, which seek to protect the interest and rights of study subjects as far as practicable. This included ensuring that no procedure caused harm or distress to the subjects, integrating the process of consenting subjects prior to enrolment with study procedures, and ensuring that the confidentiality of all subjects would be protected to the fullest possible extent.

4.0 E-waste livelihoods, quality of life and asset mapping assessment

4.1 Recyclers profile

Table 4.1 provides a descriptive summary of participants in the field study - a simple backdrop for further discussion. A total of 114 donors were involved (excluding 14 control group). Out of which 81 were e-waste workers and 33 were non e-waste workers who engaged in related economic activities on the site.

Table 4.1: Socio-demographic backgrounds of participants

Socio-demographics	Category	Frequency	%
Gender	Male	83	72.8%
	Female	31	27.2%
	Total	114	100%
Age	20 years and below	22	19.3%
	21-30 years	58	50.9%
	31-40 years	20	17.5%
	41 years and above	14	12.3%
	Total	114	100%
Level of education	None	52	45.6%
	Primary	33	29.0%
	JHS	24	21.0%
	SHS	5	4.4%
	Total	114	100%
Marital Status	Single/Never married	20	17.5%
	Married/Cohabiting	87	76.3%
	Separated	5	4.4%
	Divorced	2	1.8%
	Total	114	100%
Ethnicity	Dagomba	98	85.9%
	Kokomba	5	4.4%
	Ewe	2	1.8%
	Akan	3	2.6%
	Other northners	6	5.3%
	Total	114	100%
Place of residence	Kokomba market	55	48.2%
	Scrap yard	31	27.2%
	Agbogbloshie	9	7.9%
	Sabon Zongo	6	5.4%
	Old Fadama	3	2.6%
	Timber market	3	2.6%
	Other	7	6.1%
	Total	114	100%

Source: field work, 2014

In terms of gender, 72.8 percent of participants were male while 22.2 percent were female. This is quite expected looking at the nature of work which is male dominated. However, it is also important to indicate that activities within the yard is gendered, with women engaged in ancillary businesses including selling workers tools (hammers, chisels, spanners), cooked food, and water.

In terms of age, recyclers are mostly youthful, with eighty of them (70.2 percent) thirty years of age or below. This is hardly surprising as it resonates with an enumeration report stating that Agbogbloshie has a young population with 76.9 percent aged 35 years or below (People's Dialogue 2010). The age dynamics suggest that e-waste recycling continues to offer opportunities to new entrants, including middle-aged people, who probably have been unsuccessful in their job search or have been retrenched.

In the case of education, 45.6 percent of the participants have not had any formal education, 29 percent have had primary education, and 21.1 percent have been to Junior High School (JHS), while only 4.3 have been to Senior High School (SHS). The limited education of participants implies limited employment opportunities in the formal market, and explains their reliance on informal job opportunities.

Importantly, most participants are married or cohabitating. The implication is that many of them may have dependants, and therefore any changes in their own livelihoods may have significant impact on their families. Also, the cohabiting category may be explained by the limited and unaffordable accommodation facilities and the fact that the young men want to save enough money before getting married.

With regards to ethnicity, the result affirms the findings of Amankwaa (2014b) and show that the area is dominated by migrants from northern Ghana. However, the dominance of the Dagomba sub-group (85.9 percent) may be due to social networking, acting as a pull factor within the group. In addition, a larger proportion of the participants 72.2 percent were Muslims and this is unsurprising as Islamic religion predominates in northern Ghana.

Lastly, regarding place of residence the study reveals that 48.2 percent reside around the Kokomba market, a suburb close to the scrap yard and also a big market for artisanal works. Another 27 percent reside in the scrap yard itself, which may contribute to their lead exposure. Apart from the places of residence found in table 1, which are within the direct vicinity of the yard, other places of residence include Abossey Okai, and Ayigbe Town.

4.2 Market Descriptions

The Agbogbloshie scrap yard is an organized market, with owners, workers and self-proprietors maintaining complex relationships that have been built over the years. These relationships vary from apprenticeship and partnership to simple wage work. Many of the workers describe their journey within Agbogbloshie as one of ‘building themselves up’. In most instances, they came to the site with no money and little knowledge of the business. Through daily work, apprenticeship with established scrap dealers and a little savings, they are often able to start buying and selling scrap or finished products on their own. The first point of entry, according to most personal stories, is ‘pushing cart’—hand carts and trucks used by collectors as they scavenge the city and peripheries in search of discarded materials.

During our fieldwork, we observed a high degree of specialisation among recyclers within the scrap yard. Through working with different recyclers, wage labourers learn the ins and outs of different materials; sometimes even learning trade skills like computer and mobile phone salvage and repair, which has a highly sophisticated network within Accra. Thus, once a worker has decided how they will specialize, they often focus purely on that niche of work (e.g. tractor parts, engine blocks, steel reclamation, copper or aluminium).

Notably, we observed that scrap and junk markets are defined by their volatility. Global prices for recyclable materials are the primary drivers of the local market price, but local demand influences price as well. We also noted that recyclers are often at the mercy of the market; buying what they know to be valuable at the time and hoping that the price will stay constant or rise by the time they sell. The extreme boom/bust cycle of recyclables pricing can wipe out starters in the business.

From afar, these recyclers may appear disorganised and independent; but our findings showed they display a high degree of internal organisation and are heavily networked within the Accra recycling sector and beyond. For instance, within Agbogbloshie there is a complex network of buyers and sellers; relationships that are solidified through long-term trust-building transactions and mutual reliance. These relationships are the recyclers' best insulation against the boom/bust cycle: a mechanism founded on the ability to borrow funds or get materials on credit; smoothing over the tough times. Any changes within the market should keep these relationships in mind, both as a way of maintaining the systems of mutual support and knowing that these relationships will outlast any individual market reforms.

Moreover, there exist also, a complex web of mutual relationships which is a source of employment for many people. The recyclers are not the only people who make a living from waste materials: truck drivers, weigh station owners and a variety of middlemen are all found in this chain of work. Therefore, by thinking of waste as raw material to be exported, a positive wealth multiplier can be attached to any policy prospectus.

4.3 Value chain analysis

The field work further confirmed considerable sectoral diversity in the production process, with a chain of activities including offsite-collection, dismantling, forging (blacksmithing), repairing, burning, and metal trading. Other individuals own and run auxiliary businesses like renting wooden carts and trucks to fellow collectors, or making cooking pots from aluminium retrieved from WEEE. During the mapping process, the cooking pot industry was identified as a simple but very profitable and promising enterprise. With an average daily production of 10 pots and at a unit cost of GH¢25, the pots are sold for GH¢35-50 (depending on the size) at the nearby 'Kokomba Market' (a 10 minutes walking distance) for domestic and commercial usage. Additionally, some of the workers serve as security personnel for the yard after working hours. The e-waste chain in Agbogbloshie is segmented and scaled in patterns similar to those existing in formal economies.

An assessment of activities within the chain is important in two ways:

(1) To understand and appreciate the nature of the work, skills and dynamics within each sector and;

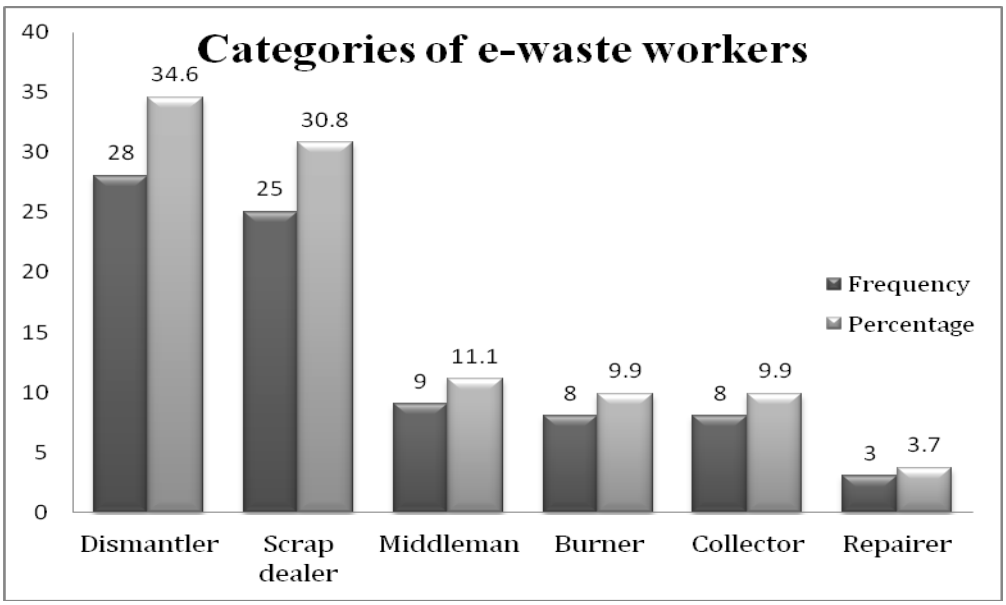
(2) To assess how these activities are connected or integrated within the larger economy.

The findings indicate that 71 percent of the participants are e-waste workers, while the remaining 29 percent are non e-waste workers. Figure 4.1 provides the categories of activities within the e-waste economy, whereas table 4.2 details the value chain description of the categories. In terms of distribution, 34.6 percent of workers are dismantlers, whiles 30.8 percent are scrap dealers. Middlemen make up 11 percent, while both collectors and recyclers/burners constitute 9.9 percent of the work force, and just 3.7 percent are repairers.

As earlier mentioned, this distribution of workers across the categories is a reflection of the total population of workers within the chain of activities estimated by the ASDA executives. It is unsurprising that dismantling emerged as the dominant work category,

because most workers particularly collectors and recyclers often double as dismantlers - as they prefer to segregate their goods into various components such as wires, plastics, casing, metal, etc to maximize sales/profit.

Figure 4.1: Categories of e-waste activities



Source: field work, 2014

Table 4.2: Value chain description of e-waste activities

Category	Description
Collectors	It is the first point of entry within the chain. They territorialize e-waste flows; by scavenging and buying e-waste in low-income, high-income and some gated neighbourhoods and IT firms through pulling of handcarts and trucks. They contribute to the emerging intermediate scrap yards in the city as they normally sell bulk goods to such scrap dealers to minimize transport cost.
Dismantlers	They disassemble e-waste into its constituent parts to retrieve reusable working components such as integrated circuit chips, functional hard drives, cases, etc. for sale to refurbishers. They also strip and segregate the non-working parts into recyclable materials such as plastic, glass and metal that are in turn sold to respective wholesalers, including the recyclers and scrap dealers.
Refurbishers (repairers)	They reuse the retrieved working parts to build (install) “new” non-branded computers, which are mainly aimed for household consumption. They also repair non-functioning equipment such as computers and motherboards. Thus, they extend the life of wasted computers and attract lots of people within the Accra retail circuit and beyond.

Recyclers (burners)	They engage in open incineration to retrieve valuable metals like copper and aluminium, and sell directly to middlemen and scrap dealers. They use insulating foam from dismantled refrigerators, or old car tyres as their sources of fuel for the fires. Thus, they create extensive secondary circuits of value from circuits of e-waste.
Middlemen	Middle men operate as link between the site and selling points to formal and informal market in Tema and other location including export to China, in the case of copper wires. Some of them are also owners of weighing scales used in weighing goods to determine their tonnage. They tend to have direct link to companies they trade with.
Scrap dealers	Highest ranked within the chain. They engage in metal trading, either directly or indirectly through agents, after they also accumulate in bulk. Their activities supply local manufacturing industries (e.g., steel rolling mills in Tema) with material inputs (industrial feedstock), thereby reducing the cost of production for the industries concerned.

Source: field work, 2014

While the above table describes the main category of work in Agbogbloshie and beyond, it is instructive to note that other categories exist, though often neglected. These include the weighers/scale owners, loaders and car cutters. Regarding the weighers, their activity is similar to the scrap dealers in that they serve as intermediaries between collectors and the companies at Tema. However, they are not directly stationed at the scrap yard. Describing the nature of the weighers' work, an interviewee noted:

> *Every weigher or scale buyer has his own customers to whom he sells his goods to. And when he is done with his loading, he goes to his own company that he normally sells his goods out to. They do not rely on one specific company– even the scrap dealers here; we have so many companies that we do business with them*. (Scrap dealer, workers focus group discussion)

The services of loading boys are solicited when e-waste materials have been weighed and needs to be loaded into a truck for transportation to Tema. Car cutters slice old vehicles into sizes that can be worked on or transported to Tema. Interestingly, there appears to be some employment and social mobility within the value chain. Both go hand in hand – as one climbs up the occupational ladder, one's social status also appreciates.

Most workers start as collectors, which is the first point of entry into the business. Though some also starts as apprentice working under a master; masters usually remunerate

their apprentices with daily wage allowance[5]. However, moving up the ladder also implies accumulation of capital over some years. A detailed description of occupational mobility is provided in this observation:

> *Most of us have masters we serve. And at the end of the day, the master will pay you for work done. You can save part to start your own business. Thus, your master can support you to start your own business.* (Dismantler, workers focus group discussion).

Most previous debates on e-waste have overlooked the multiple livelihoods strategy that people are engaged in. Admittedly, while the e-waste business seems to be the dominant activity, many also possess various skills that are used to earn additional income. Some participants mentioned that they are engaged in masonry, carpentry, plumbing and in-home electrical repair. Others are not necessarily engaged in artisanal works but rather are involved in other businesses, including being housing agents. For instance one participant noted:

> *…for me I am a house [room] dealer, when I get a house [room] like this I buy it. Then later rent it out to someone who needs a room. That is my business aside repairing.* (Repairer, workers focus group discussion).

Adding these other livelihood strategies together, we noted that out of 114 participants, only 22 percent had secondary jobs, while 78 percent were solely engaged in the e-waste business. Moreover, 84 percent had never engaged in other informal business before entering their current e-waste business.

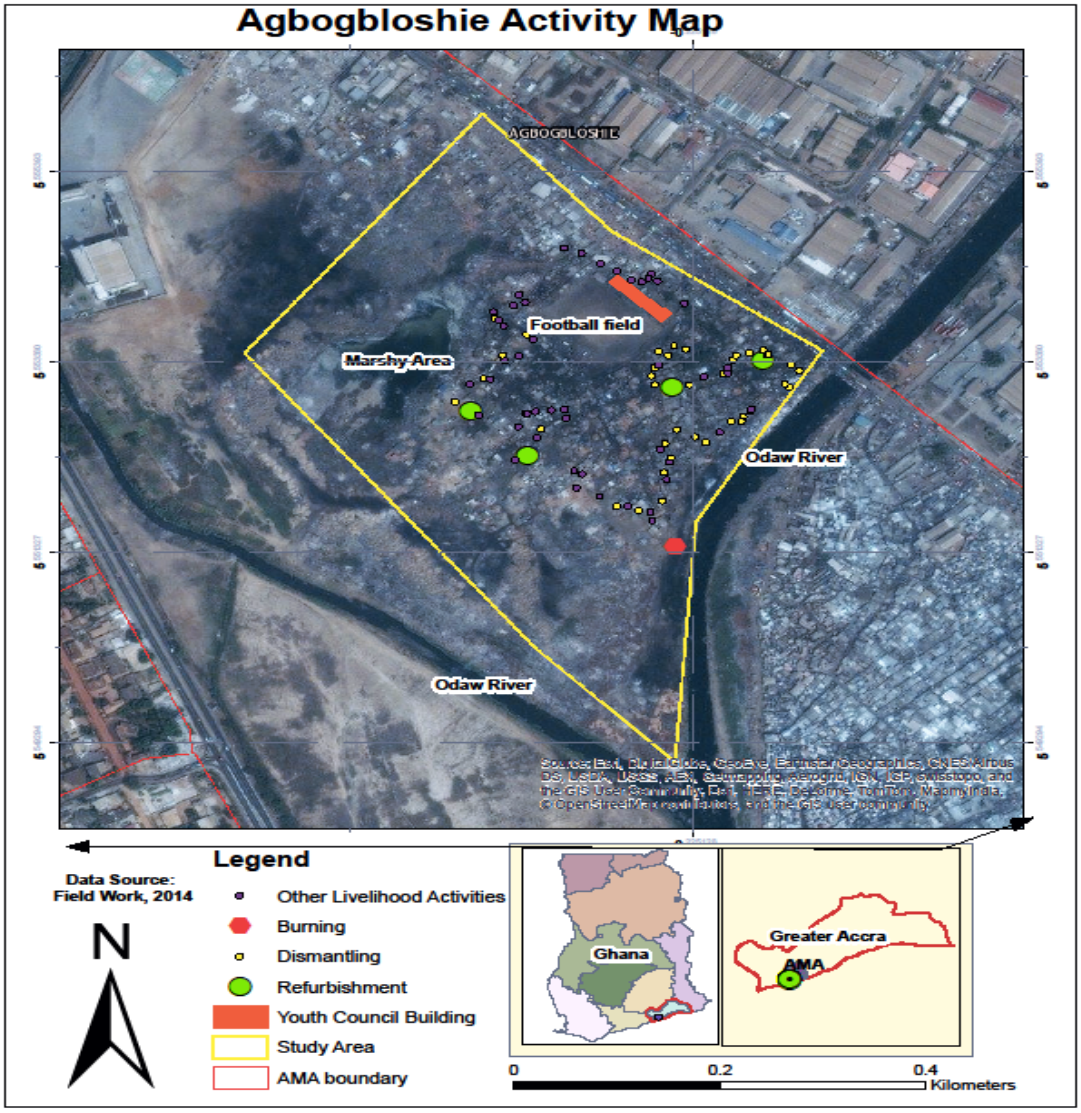
Figure 4.2 illustrates the activity map of Agbogbloshie as captured during the study. The map shows the major economic activities on the site, which includes: burning, refurbishing/repairing and dismantling. Our study also captured numerous other livelihood activities, such as assembling points where collectors sell their materials and scrap dealers pile goods to sell in bulk. Also, it includes joints for wooden carts renters where workers pay GH¢ 3 to hire the trucks for their daily scavenging expeditions. Petty trading shops for tools such as hammers, spanners, and chisel are included along with vending outlets for water, meals and other daily amenities.

In looking to the future, many participants said that returning to their homes in the north is not a priority, but they did emphasise their obligations to support those that they had left behind. With this background, some respondents said they invest some of their

[5] Use of master emphasizes the dominance of men in the e-waste business in Agbogbloshie. Masters are business owners who offer apprenticeship training for new entrants.

savings in businesses back home to support themselves and their families. While the income is important, interviewees claimed that investments back home are to demonstrate that they are doing well in Accra.

Figure 4.2: Activity map of Agbogbloshie



Source: Authors' construct, 2014

4.4 Interconnections of e-waste within the urban space economy

Our study further corroborates findings from previous studies indicating the interconnectedness of the e-waste chain of activities with other key sectors of the economy, both within the formal and the informal sector (Grant and Oteng-Ababio, 2012; Oteng-Ababio and Amankwaa, 2014). We found two main connections, involving:

(1) occupational linkages with businesses within the e-waste chain at Agbogbloshie and;
(2) linkages with other key sectors of the urban economy.

This is in tandem with Grant and Oteng-Ababio's (2012) statement of "circuitry within commodities themselves" and "intersection with formal industries, international agents, and firms and agents beyond the borders of Ghana".

It is important to explicate the advantages inherent in the two types of linkages. Apart from improving social relations and building long-term trust and mutual reliance, it also facilitates the processes of specialization, which is a key conduit for innovation and creativity. Innovation and creativity are important features of the business, especially those within the refurbishment industries. The possibilities fostered by innovations and creative thinking on-site may migrate to other urban industries off-site; meaning that these industries deserve protection and support from municipal officials and national policy makers. Additionally, protections for e-waste work will ensure market endurance throughout the value chain. For instance, the collector who is assured that his scraps will be bought by a dismantler, or scrap dealer, upon arrival on the site; and before this, he is assured of getting a truck to start the day's business by hiring from the truck renters.

Our study also indicates the importance of Tema within the web of interrelations especially with the outside world and other formal establishments. Tema is a key industrial centre with firms that depend on scrap metals (e.g. aluminium, iron and copper) as raw materials for their productive activities. In addition to Tema, there are other industries in Accra that also rely on scrap. This point was illustrated by one interviewee:

> *Companies in Tema that buy our scrap include: the Tema Steel Company Ltd, Ferro Fabrik Ltd and Santu Steel. There are many others too, some local, which buy the scraps most especially aluminium. Apart from the companies in Tema, some in Accra here also purchase scraps from Agbogbloshie.* (Scrap dealer, workers focus group discussion)

The existing connections within the value chain are based on informal relations, which are inheres with advantages and disadvantages. One disadvantage is the volatility of market prices. The uncertainty in pricing has in many cases led to losses for dealers. In order to hedge against losses many scrappers cooperate with some middlemen stationed at Tema who provide information about prices and the firms that are willing to pay promptly. These brokerage and market forecasting services are vital to any scrapper, but cost money.

As an illustration, various companies in Tema have hired permanent agents who act as market informants in Agbogbloshie. This seems to provide a ready market for recovered items from the site. Similarly, some foreigners (who have delegated representatives through the local association-ASDA) buy from these "betweeners" – though it is unclear which classes of items they buy. Discussants said that the "betweener" agents are extremely helpful to their business operations, because the 'white folks[6] are also the main exporters of scrap to other countries. This group is different from the Tema companies, which deal with local manufacturing of building materials (e.g. iron rods) and other relevant metal ingots. In this regard, the importance of Agbogbloshie within this circuitry is made clear as:

(1) the supplier of scrap metal to local industries and;

(2) the supplier for export.

The impact of the waste business transcends those direct connections to the wider urban economy. For instance, the impact of e-waste recycling on ancillary business like food vending and retail outlets cannot be overemphasized. Women hailing from northern Ghana have found a steady living in the support industries (e.g. cooking, or amenities vending). With regards to the proportion of participants involved in non-e-waste activities, food vending constitutes the largest non-e-waste trade activity, followed by beverage sellers, water vendors, and petty traders. This diversity has implications for work dynamics and mobility patterns. For instance, because time is an essential component of the e-waste work, the chop bar and food vendors provide readily available food to the workers, saving them work time and transportation costs.

In addition to drinking potable water, recyclers purchase sachet water to cool their recovered materials before sending them for weighing and subsequent trading. Also, most of the workers buy the water to prepare themselves for ablution, which is vitally important given the predominance of Muslims on-site. The clothing traders also provide on-site service by selling affordable second-hand clothing to workers. Cheap clothing is necessary because most workers often dispose of soiled clothing regularly.

Beyond this, the field work observed the emergence of financial institutions such as private banks, microfinance companies, and mobile money centers (which provide platform

[6] An amorphous group usually comprising non Ghanaians including Chinese, Lebanese, Indian and Pakistanis

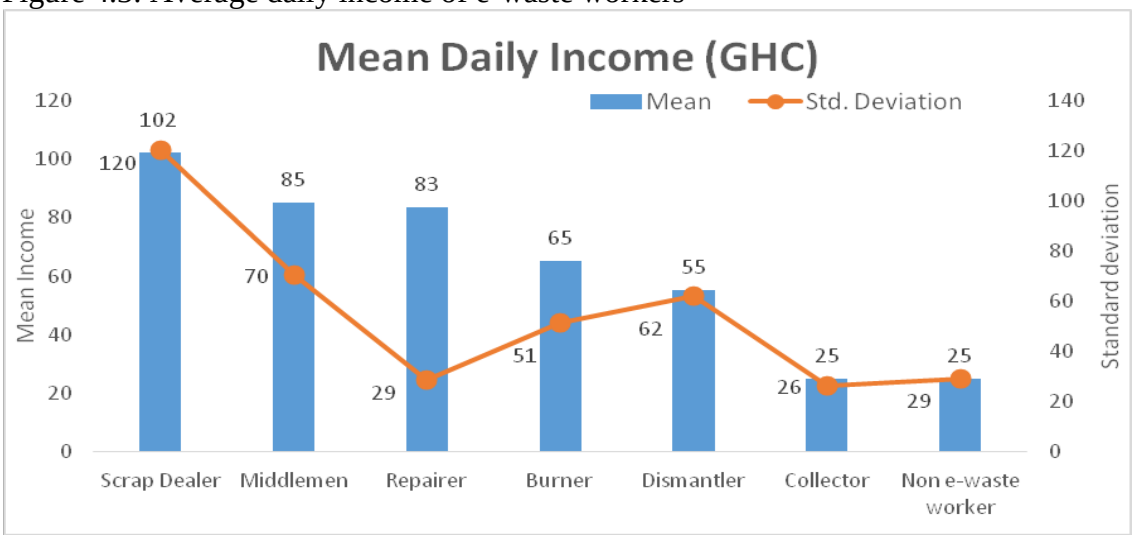
for people to receive and send money) dotted in close proximity to the site. It was discovered that some recyclers have saving accounts, and life insurance policies while others secure loans for their business. The mobile money platform also minimizes mobility, facilitates transaction with business counterparts and helps remit money to families back in the north.

4.5 Quality of life (QoL) assessment

QoL is a multifaceted concept (Cruz et al., 2011). For the most part, it involves assessment of how individuals perceive their lives (Zaid and Popoola, 2010). QoL is studied by criminologists, sociologists, urban planners, and geographers. Despite widespread interest in QoL, no single framework exists for its measurement (Stephen, 2013). Nonetheless, Tua Seik's (2000) approach to QoL based on an 'individual's satisfaction with life' is adopted for this study. Seik's measures include both objective and subjective aspects of QoL. However, in this study, we rely mainly on subjective indicators. We focus largely on income, job satisfaction and ranking of basic social and physical infrastructure. Although subjective variables have lower data reliability, they retain high validity (Seik, 2000). The use of subjective proxies is informed by rapid urban dynamics, the vicissitude of urban living, and unequal opportunities that it presents to its dwellers (Rogerson, 1999).

The study revealed that income earned per day relates directly to the category of employment (figure 4.3). Scrap dealers occupy the highest echelon and therefore earn relatively high average income (GH¢102). This is followed by the middlemen who link other scrappers with final buyers. Income earned by collectors (GH¢25) is consistent with studies by Prakash et al. (2011) who found that collectors earn relatively less (about GH¢30).

Figure 4.3: Average daily income of e-waste workers



Source: field work, 2014.

The income levels indicate that e-waste livelihood has the potential to reduce poverty, if they are given the needed support, because average daily incomes are higher than the daily minimum wage (GH¢ 6). For example an average collector earns a monthly gross income of about GH¢750. Despite the vicissitude in earnings and daily expenditure including water and sanitation, bathing, food, and hiring of push trucks, the results are higher than that of an average public servant in Ghana who earns approximately GH¢180 a month. This might explain why e-waste chain of activities remains the second largest employment category for the 79,684 residents of Agbogbloshie after retailing (Armah, 2008).

Another dimension investigated using QoL involved job satisfaction. During the field work, workers were asked to rate their level of job satisfaction. Scrap dealers rated 7 on a 1-10 scale, repairers rated 5/10, dismantlers 5/10 and burners 6/10. Although not straightforward, there seems to be a relative consistency between job satisfaction and income. We however propose further interrogation of this finding since this is imperative for any quality of life assessment.

In addition to income and job satisfaction, workers were asked the number of days a week that they work, and how many hours per day. Most workers, about 48 percent, worked 6 days within the week, whiles 47 percent worked 7 days within the week. And 77.8 percent of the participants worked between 36 and 70 hours per week (5 - 10 hrs a day) while 22.2 percent operated between 71 and 105 hours per week (11 - 15 hrs a day). The long hours and high levels of work satisfaction reported suggest that most respondents find both meaning and substantive remuneration from their work.

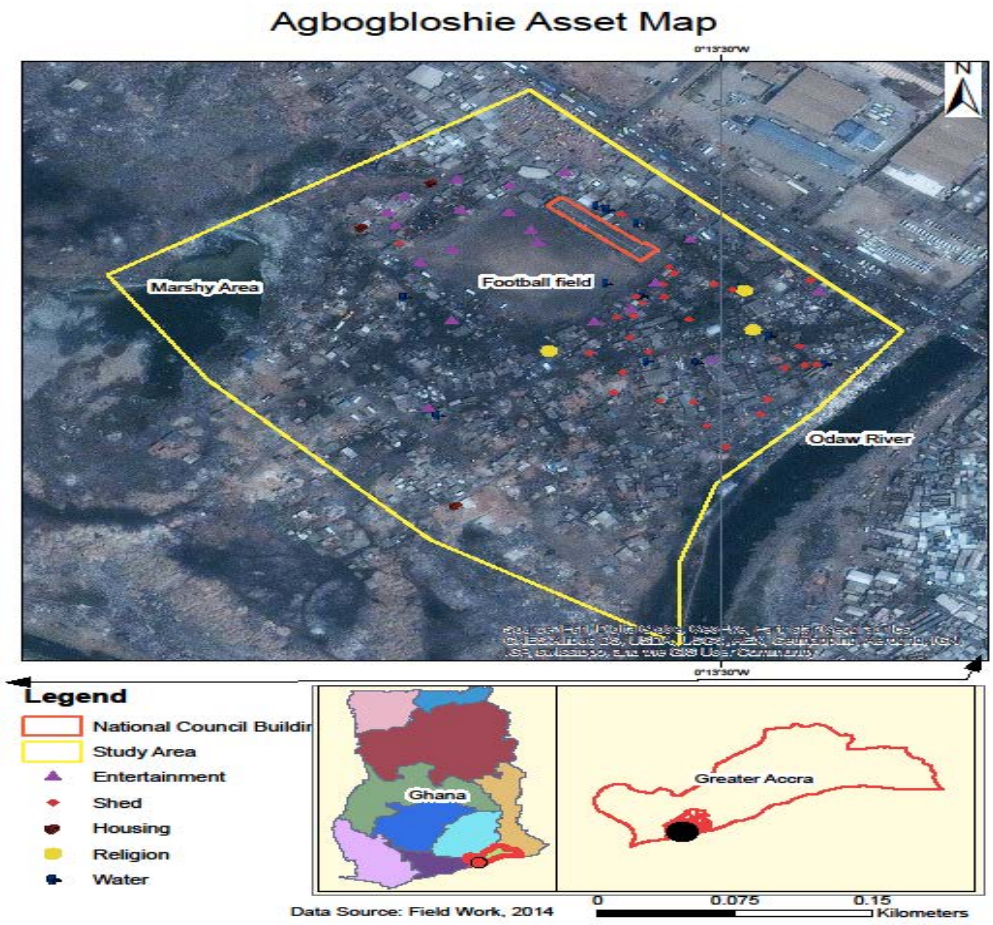
4.6 Asset mapping assessment

Figure 4.4 presents the asset map of Agbogbloshie as captured during the participatory community asset mapping process. The assessment of quality of life (QoL) was based on two sets of discussion with participants from the Agbogbloshie scrap yard. One with the leadership of ASDA and the other with recyclers engaged in various e-waste activities within the scrap yard. The leaders' session largely focused on assets required for their business: the factors, conditions, and variables needed to make business viable. The discussion further disaggregated them into physical, and social/cultural factors.

The factors were then ranked as needs and assets by the participants themselves, as seen in table 4.3. The workers' session largely concentrated on the state of the assets by way

of scoring on a scale of 1-10; with one being the highest score while ten represents the lowest score. Tables 4.3 and 4.4 show the subjective assessments as to the assets' influence on quality of life. For instance, in table 4.3 shed[7] is ranked highest with a score of one. Therefore, shed is considered the most important physical asset to both workers and the leadership. This is unsurprising, because apart from being a place of work, it also ensures security for most working equipment, rest, and serves as a temporary living space. Shed is thus a relatively more important physical asset than roads, housing or storage facilities.

Figure 4.4: Asset map of Agbogbloshie



Source: Field work, 2014

Table 4.3: Ranking of physical and social infrastructure

Variable	Rank
Physical infrastructure	
Shed	1
Road/street	2

[7] Temporary wooden structure and metal container used as work space for various activities

Housing	3
Storage facility	4
Social infrastructure	
Healthcare	1
Education	2
Electricity	3
Toilet/sanitation	4
Water	5
Religious facilities	6
Security	No rank
Entertainment	No rank

Source: Field work, 2014

In terms of social assets, health care facilities are ranked as the number one most important whereas security and entertainment received the lowest scores. During our field work, we did not record any health care and educational facility on or nearer to the site. The workers reported these twin absence as highly detrimental because they have to travel long distances to access basic health care and daily education. Education seems to be a key worry for workers as it is perceived as necessary to secure a future for their children. Table 4.4 ranks the present conditions of existing assets on the site. The table shows that the general level of physical infrastructure is poor, providing a clear indication of the neglect of this area by city authorities. For instance, road conditions are deplorable and needs urgent attention.

Table 4.4: Workers scoring of conditions of assets within the yard

Variable	**Rating**	**Description of current condition**
Roads	2/10	Very bad
Water	5/10	Okay, but not suitable for drinking. Workers drink sachet water instead.
Baths/toilet	5/10	Somewhat okay, but owned by private operators.
Electricity	1/10	Very bad and erratic. Majority of the workers tap power from the few facilities/structures which have connection, and they contribute money to reload the pre-paid meters. Overconsumption by some people is a problem.
Security	8/10	Security is good, people are paid to look after goods at night. They work in shift.
Leadership	5-8/10	This was a split as four gave 5/10 and another four 8/10. Despite a decrease in their influence, they seems to have done well when workers have issues with the city authority and law enforcement
Co-operation with government	5/10	They do not have much problem with the government, however their only concern was a fiat given by the city authority banning the collectors from plying on the main roads of the CBD
Health care	1/10	No visible clinic on site, minor illnesses are self-medicated while major health issues are attended to at Korle Bu. Not affordable
Education	0	No school within site beyond nursery, children trek several

		kilometres to school.
Entertainment	8/10	Several drinking bars on site, nearby beach frequented by workers. High use of social media activities: facebook, Whatsapp, and computer games. There is also a football park.
Housing	1/10	Not affordable. People share sleeping spaces and pay per night.
Religious facility (mosques)	8/10	Islam is the most dominant form of religion of workers here. Christians use the youth building on site for worship on Sundays. But Muslim workers would prefer a dedicated building instead of the present wooden structures that exist

Source: Field work, 2014

5.0 E-waste recycling and Blood lead levels (BLLs)

5.1 BLLs among participants and control group

Lead remains one of the major heavy metal contaminants during the process of e-waste recycling. Consequently, attempts were made to evaluate the concentration of lead in the blood of sampled participants at the site. A total of 128 blood samples were analysed, comprising 81 e-waste workers, 33 non e-waste workers (traders), and 14 control unit (office workers in University of Ghana). According to the diagnostic criteria for BLLs defined by the US Centers for Disease Control (CDC, 1991), children with BLLs greater than or equal to ten micrograms per deciliter (≥10.0 µg/dL) often have elevated BLLs. Similarly, in 2009, the Adult Blood Lead Epidemiology and Surveillance (ABLES) program of the U.S reported its case definition for an elevated BLL as a blood lead concentration greater than or equal to 25 µg/dL (CDC, 2009). Table 5.1 presents participants' mean BLL.

Table 5.1: Descriptive statistics of BLLs among e-waste and non e-waste workers and control group

Category	***N***	**Range**	$x \pm s$	≥0.001 µg/dL ***n (%)***
Total	***128***			***53 (41.4)***
E-waste	81	0.50-18.80	3.49±3.54	36 (44.4)
Non E-waste	33	0.30-8.20	3.54±2.50	17 (51.5)
Control	14	0.00-0.00	0.00±0.00	0 (0.0)

The comparative mean t-statistics of e-waste and non e-waste workers is -0.05 and the probability is 0.52; and e-waste workers and control group is 3.04 and the probability is 0.01.
Below detection limit (BDL) is <0.001 µg/dL. Source: Field work, 2014

The table reveals that the mean BLL of non e-waste workers was slightly higher (3.54 µg/dL) than that of e-waste workers (3.49 µg/dL) although higher BLLs ranges were found among e-waste workers (0.50-18.80 µg/dL) than non e-waste workers (0.30-8.20 µg/dL). Overall, no case of elevated BLL was found in the sample. However, there were instances of high BLLs recorded among the e-waste workers. Since studies show that low blood lead concentrations—even less than 10 µg/dL—are inversely associated with adverse health

effects (Canfield et al., 2003; Lanphear et al., 2005) this may be a cause for concern. Among e-waste workers, 44.4 percent of them (36/81) had BLLs above the detection limit (0.001 μg/dL), compared with 51.5 percent of non e-waste workers (17/33). A t-test analysis gave a value of -0.05 at a significant level of 0.52, implying that there is no significant difference between the BLLs of e-waste and non e-waste workers. This indicates that in addition to the e-waste chain of activities having a bearing on workers' BLLs other factors such as working years and time spent on the site are significant contributory factors. Quite expectedly, the results further show that the mean BLL of e-waste workers was significantly higher than the control group ($p=0.01$) at 1 percent significant level. The implication of this for a national regulatory framework is quite salient.

Clearly, the results have revealed that the pathway for participants to have accumulated lead is varied including, through dermal contact, ingestion and/or inhalation as e-waste contaminants might have spread into the air via dust and smoke. A study by Ha et al. (2009) reveals that e-waste workers in Bangalore, breathe dust laden air containing Pb.

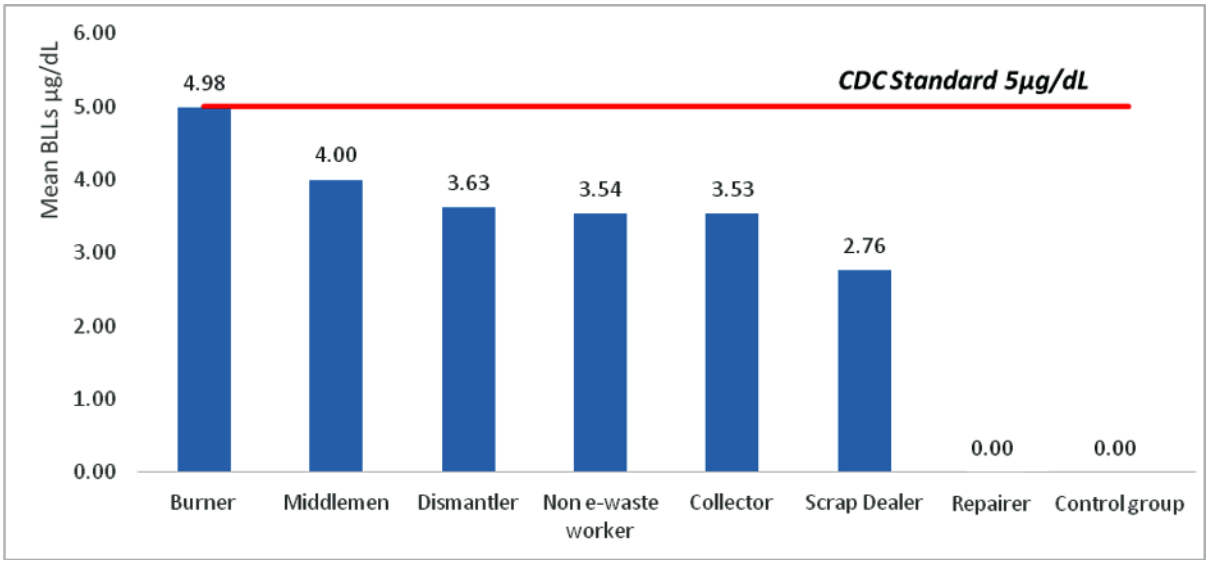
5.2 BLLs and e-waste occupational variations

Although the general trend showed lower BLLs when compared to the US CDC standard (10 μg/dL for children and 25 μg/dL for adults), attempts were made to seek occupational variations in the distribution. Figure 5.1 compares the BLLs of the various work categories with the US CDC standard. The results indicate activity-specific human exposure to lead from e-waste recycling depending on the processes and modus operandi at each stage of the chain. The mean BLLs from the different occupation categories were in the following descending order: Burners/Recyclers (4.98 μg/dL) > Middlemen (4.00 μg/dL) > Dismantlers (3.63 μg/dL) > Collectors (3.53 μg/dL) > Scrap dealers (2.76 μg/dL) > Refurbishers/ Repairers (0.00 μg/dL).

The results demonstrate that the burners/recyclers recorded higher BLLs than the other work categories. Recyclers specialize in extracting valuable metals from equipment through open burning. The recycling category has ostensibly become a transit point for most new entrants who are enticed by the opportunity to access quick cash in the short term. Once they are established, they graduate to the next level within the e-waste hierarchy. Although a transient category, because the recyclers use insulating foam from dismantled refrigerators, or old car tyres as the main sources of fuel for the fires, they may still be exposed to lead through direct contact or inhalation of lead vapour. These explanations may account for their

high BLLs. Remarkably high concentration (18.8 µg/dL) of lead was found in the blood of a 23 year old burner who had worked for 4 years with a working time of 98 hours per week.

Figure 5.1: BLLs of the various categories of work and the US CDC standard



Source: Field work, 2014

Middlemen are intermediaries who provide a micro level and easy market for collectors and recyclers who have gathered relatively small materials and lack the economic advantage to access the scrap dealers market. They are mostly found on the site weighing and handling all sort of materials from collectors and recyclers and other traders before or after processing. Generally, most of the middlemen were participants with considerable longer working years and hours and this possibly might have contributed to their high BLLs.

The dismantlers specialize in equipment categorisation, sorting, and separation to recover valuable metals. Their activities involve manual dismantling of all kinds of equipment and they are virtually involved in all the activities of the various actors on the site. Most of them stay and work at the site for longer periods and their exposure to lead through direct contact or inhalation of lead vapour might have contributed to the observed BLLs.

The activities of the collectors are beset with several risk exposures, as they ply major trade centers to gather waste materials. Even though some collectors are occasionally involved in rudimentary dismantling of their goods, the majority spend relatively less time at the site. This combined with the fact that the collection category remains the entry point for most participants perhaps explains the comparatively low BLLs among collectors.

Scrap dealers comprised workers who trade in metals and other valuable materials and occupy the top hierarchy in the e-waste chain. Although, most of the scrap dealers were participants who had worked at the site for a considerable length of time they spend less time on the site as many of them now move out to shops and offices to increase their business opportunities. Thus, their relatively short working hours may possibly account for the low BLLs observed.

The repairers/refurbishers had the lowest BLLs among the workers categories. This is surprising since repairing activities mostly involve using electric solder which is a major source of lead. Yet, further interaction with the three (3) repairers on the site revealed that the refurbishing business is still in the developing stages. And they prefer to cannibalize the unserviceable equipment for workable components to repair others for the second-hand market than engage in other repairing activities such as lead soldering. Also, it was observed that the repairers were mostly in their container shops and they were not severely exposed to the fumes from the burning activities as compared to the other actors at the site. It can be suggested that environmental and working conditions including the make-up (type of material) and positioning of refurbishing shop possibly influence workers' exposure to lead.

As earlier noted, there was no significant difference between the various e-waste categories and non e-waste workers, and by implication the e-waste workers like their non e-waste counterparts are at similar risk. This observation merits some consideration since recyclers still use crude recycling methods with little consideration for their health. Thus, it is conceivable that there is the possibility of lead contamination spreading to immediate environments in dust, water and air contributing to the observed BLLs of e-waste and non e-waste participants. These realizations therefore make it imperative to consider the interplay of other related factors that may influence participants' BLLs.

5.3 Relationship between BLLs and age, working years and hours

The study further explores the relationship between some socio-demographic backgrounds and participants' BLLs. These background traits include age, the number of years spent in the business and weekly working hours. The results show that BLLs in e-waste workers tend to increase with age; older participants tend to have higher BLLs than younger ones. For instance, the workers below 20 years had a lower mean BLL (1.95 µg/dL) while those between the age categories of 21 and 30 years and 31 to 40 years had a higher mean BLLs of 3.38 µg/dL and 4.27 µg/dL respectively. Although the mean BLL of workers above

40 years was 3.67 µg/dL, the result is still significant especially when majority of participants in this age category are scrap dealers who tend to spend less time on the site.

This observation resonates with the work of Huo et al. (2007) which showed that older men tend to have higher BLLs than younger ones. According to them this might have resulted from the former's increased exposure over time coupled with their lower rate of excretion. It must be acknowledged that, though younger ones are particularly vulnerable to lead contamination because they absorb more lead from their environments, they also have high rate of excretion (Hu et al., 2007).

The study also explored whether participants' working years and hours predispose them to higher BLLs. Table 5.2 presents the mean BLL of e-waste workers and their respective years of work and weekly working hours. In terms of working years, the study reveals that participants' number of years spent in the business ranged from 1 to 20 years with majority of them (75.3 percent) working for less than 10 years while the remaining 24.7 percent have worked for 10 years and more. The results show a negative relationship between higher BLLs and the number of years spent in the business. For instance, scrap dealers who recorded the highest mean working years of 8.7 had the lowest BLL (2.8 µg/dL) whiles the burners who had the lowest mean working years of 5.8 had the highest BLL (4.9 µg/dL).

Table 5.2: Mean BLLs of e-waste workers and their years of work and weekly working hours

Category	Burner		Middlemen		Dismantler		Collector		Scrap Dealer		Repairer	
	Yrs	Hrs	Yrs	Hrs	Yrs	Hrs	Yrs	Hrs	Yrs	Hrs	Yrs	Hrs
Mean	5.75	78.25	8.11	76.33	5.89	76.82	6.50	67.62	8.68	75.48	6.00	74.00
Standard Deviation	5.04	16.99	5.23	10.93	4.53	9.99	4.11	20.13	6.08	10.69	1.00	17.32
Mean BLL	4.98		4.00		3.63		3.53		2.76		0.00	

NB: Yrs and Hrs denote years of work and weekly hours of work respectively

In the case of working hours, the results showed that 77.8 percent of the participants worked between 36 and 70 hours per week (5 - 10 hrs a day) while 22.2 percent operated between 71 and 105 hours per week (11 - 15 hrs a day). Clearly, the results indicate that BLLs in e-waste workers correlate positively with working hours. Table 5.2 shows that burners recorded the highest mean working time of 78.3 hours per week followed by dismantlers who had 76.8 hours per week with scrap dealers, repairers and collectors recording the lowest mean working time of 75.5 hours, 74.5 hours and 67.6 hours

respectively. A t-test analysis gave a value of -2.87 at a significant level of 0.007, implying that there is significant difference between working hours and BLLs, and that the difference in lead concentrations among the categories of working hours is not due to chance. This finding reiterates the earlier claim that longer working hours or stay at the site tend to have a positive bearing on participants' BLLs.

The findings of this study relates to that of Caravanos et al. (2011) which identifies a higher concentration of lead in air which is over 4 times the permissible USEPA ambient air quality levels at Agbogbloshie. This confirms earlier submission that participants' vulnerability to lead contamination is not only through direct contact (e.g. burners) alone, but equally through the long exposure to contaminated air as amply demonstrated by the situation in the study area. Thusly, it is possible that those who trade at the adjourning food market or stay at the nearby settlements may equally be at risk.

5.4 Regression analysis of BLLs and related factors

The study further sought to identify the factors that influence the BLLs of e-waste and non e-waste workers. So far, the literature demonstrates inadequate research on e-waste recycling and associated workers' BLLs in Ghana. However, common factors reported by studies outside Ghana were demographic and social habits characteristics. The demographic characteristics include; age, gender, and residence while the social habit/lifestyle variables entail smoking, alcohol intake, hand washing, and frequent changing of work clothes. Tables 5.3 and 5.4 present a Tobit regression model of the factors that influence participants' BLLs.

Table 5.3: Tobit model general parameters

Parameter	***Value***
Number of observations	*53*
F (7, 49)	*2.91*
Prob > F	*0.01*
Pseudo R^2	*0.04*
Log pseudo likelihood	*-131.58*

Source: Authors' computation, 2014

Table 5.4: Parameter coefficients of Tobit Regression model for factors that influence BLLs

Variable	Coefficient	Standard Error	P-value
Gender	0.765	0.808	0.349
Age	0.004	0.045	0.924
Residence	2.050	0.811	0.015**
Alcohol intake	2.764	1.915	0.156
Smoke	-1.872	1.819	0.309
Wash hands	-0.758	1.015	0.459

Change clothes	-1.337	0.795	0.099
Constant	*0.913*	*1.836*	*0.621*

Source: Authors' computation, 2014

The results show that the overall goodness of fit of the Tobit regression model is significant at one percent. This implies that all the independent variables in the model jointly explain the variations in the dependent variable (participants' BLLs) at a precision of 99.9 percent. However, the R Squared value was very low.

Furthermore, the results reveal that only two variables have a significant relationship with amount of lead in blood of e-waste and non e-waste workers. These were residence and frequency of changing work clothes. Residence was measured as a dummy variable where the a priori hypothesis was that e-waste and non e-waste workers who permanently reside at the site would record higher BLLs compared to those who only come to the site to work and sleep elsewhere. This a priori hypothesis was met and the coefficient of 2.05 suggests that residents at the site are more likely to record 2.05 µg/dL of lead in their blood more than their counterparts who only work at the site. This variable was significant at one percent implying that we are 99.9 percent sure about making this claim. This supports the claim that people who spend more time at the site have higher risk of BLLs than those who do not.

Again, participants' frequency of changing their work clothes was also measured as a dummy variable where those who change their clothes everyday were expected to record lower levels of lead in their blood compared to those who seldomly change their clothes. The coefficient was negative implying that our a priori hypothesis was met and the magnitude was -1.34. This implies that, not changing work clothes everyday by e-waste and non e-waste workers can increase their lead levels by 1.34 µg/dL compared to their counterparts who change their clothes every day. The level of significance of this variable was 10 percent implying that we are 90 percent accurate in making this claim. This finding is important since participants who do not change their clothes frequently can potentially increase their household members' (particularly children's) exposure to lead and increase their BLLs. This is most likely because their working clothes normally end up in the household or are mixed with other household dresses, especially before and during washing.

The rest of the variables were not significant but had signs that meet our hypothesis. Age, gender, and alcohol intake meet our a priori expectation which is males, elderly people and those who drink alcohol tend to have higher lead levels in their blood compared to their

other counterparts. However, the sign for smokers did not meet our a priori expectation which we believe is attributable to they being occasional smokers (see table 5.5).

Table 5.5: Measurement of variables for regression model

Variable	Description	Measurement	*A priori* sign
Gender	Gender of workers at site	1= Male 0= Female	+
Age	Age of workers at site	Age in years	+
Residence	Workers place of residence	1= Resident at site 0=Otherwise	+
Alcohol intake	Alcohol intake habits	1= Takes alcohol 0=Otherwise	+
Smoke	Smoking habits	1=Smokes 0=Otherwise	+
Wash hands	Washing of hands	1=Yes 0=No	-
Change cloths	Frequent changing of cloths	1=Everyday 0=Otherwise	-

NB: the signs are stated with respect to the amount of lead expected to be in blood samples of workers (dependent variable).

5.5 Job orientation and risk burden

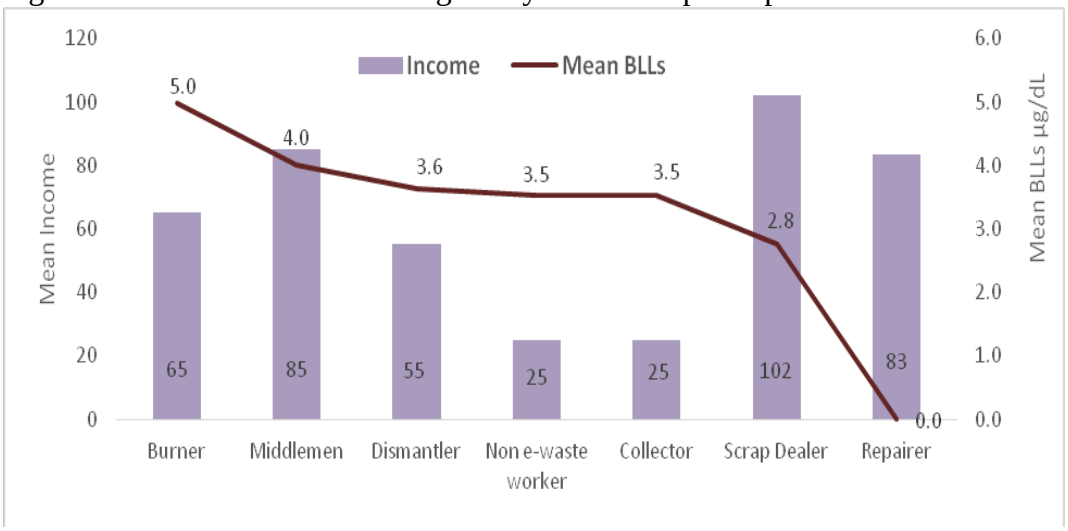
The study explored the extent to which workers gave priority to economic rewards (income and job progression), and/or occupational health rewards (environmental quality and health safety). Unsurprisingly, given the diversity and complexity in the e-waste economy and the variations in income of workers within the six occupational categories, income remains a high priority. Indeed, a desire to climb the income scales as quickly as possible was a motivating factor for job progression desired by most workers. Majority of the participants had ambitions to reach senior positions such as middlemen and scrap dealers and on this basis could be seen to have some economic reward orientation. Only a remaining handful of workers had no such ambitions and were happy to remain at their present level while working to improve their occupational and environmental conditions, and on this basis could be seen to have some occupational health reward orientation.

The results illustrate that there is discernible pattern between one's position in the e-waste chain and average daily income and BLLs. At the apex of the income ladder are the scrap dealers who on the average earn GH₵ 102 per day. Just below them are the middlemen, who averagely earn up to GH₵ 85 daily. Refurbishment is a steadier income stream, and earnings average GH₵ 83 per day. Recyclers, dismantlers and collectors were the lowest earners recording averagely GH₵ 65, GH₵ 55 and GH₵ 25 per day respectively.

Figure 5.2 shows the mean BLLs of e-waste and non e-waste workers and their average daily income. It is worth noting that despite the economic reward orientation of most workers, some variation in BLLs emerged by income category of workers. While scrap dealers who occupy the highest echelon at the site and the top earner recorded the lowest

BLLs (2.8 µg/dL), collectors who are at the bottom of the chain and the lowest earner had higher BLLs (3.5 µg/dL).

Figure 5.2: Mean BLLs and average daily income of participants



Source: Field work, 2014

This finding is important as it suggests that the "poor earners" among the six occupational groups face adverse health effects. This uneven weight of occupational health risks borne by the marginalised in the e-waste economy contravenes the principles of environmental justice, which seeks to ensure equitable spatial distribution of environmental risks (in combination with broader social and economic justice issues) irrespective of class, nationality, ethnicity, gender or religion. Clearly, this suggests unequal risk burden among workers at the Agbogbloshie e-waste site with the lower income earners recording higher BLLs. We highlight that, this observation of possible ‘environmental-economic injustice’ constitutes a useful frame for further work at the site that can unravel on-the-ground realities of the factors that perpetuate the current situation and ensure targeted interventions.

5.6 E-waste recycling and BLLs – a retrospect

To the best of our knowledge, this study of workers at the Agbogbloshie e-waste site reveals the first insights into the occupational risks these workers face in terms of BLLs, apart from Amankwaa's (2014a) work that piloted a smaller sample. We observed that the processing of e-waste in Agbogbloshie is rudimentary and the recycling industry depends mainly on manual processing. Despite the fact that the coordination of e-waste recycling is well organized in occupationally-segregated small business units, manual processing and burning of e-waste has contributed to concentration of lead in the workers. Examination of the possible impact of the e-waste industry on the BLLs of workers in Agbogbloshie revealed

that non-e-waste workers had higher BLLs than e-waste workers though the latter had a higher range of 0.50-18.80 µg/dL than the former (0.30-8.20 µg/dL), and there was no significant difference between them.

However, there existed significant variations in the BLLs of workers within the value chain of e-waste activities with recyclers (burners) recording the highest BLLs with repairers registering the lowest, suggesting a correlation between the BLLs and the occupational type. This observation is important and confirms the assertion of some environmental NGOS's (Greenpeace, BAN), and international media (Frontline, Afrol News) that those engaged in burning bear the greatest risk of informal recycling practices; because of their direct contact with the fumes from burning. We speculate that the BLLs in e-waste workers may be caused by direct exposure to lead during e-waste recycling while that of the non e-waste workers may be due to the lead contamination in the environment. However, this requires further study to determine the relationship between BLLs in both e-waste and non-e-waste workers and the actual lead contamination in the environment.

The study also demonstrates significant increasing trend in BLLs with certain factors such as residence at the site, working hours, increasing age, and frequency of changing work clothes. For instance, older participants tended to have higher BLLs than younger ones and this might have resulted from the former's increased exposure over time coupled with their lower rate of excretion. The level of lead excreted in urine reflects a person's body burden or long-term exposure in developing any symptom like renal damage (Lanphear et al., 2005). Other factors that might influence the risk of lead toxicity in adults include pre-existing diseases affecting relevant target organs (e.g., hypertension, renal disease, or neurological dysfunction), nutritional deficiencies that modify the absorption or distribution of lead (e.g., low dietary calcium or iron deficiency), advanced age, and genetic susceptibility (Kosnett et al., 2007). We recommend that further studies are conducted into the health effects of lead concentration in the blood of the workers at the site.

The lead exposure among women working and living on the site is particularly worrying. Prenatal exposure to lead tend to affect several parameters in a developing child (Bellinger, 2013). Studies from China indicate that elevated blood levels of Cd and Pb impair growth, activity levels, adaptability, and mood in children living in e-waste areas with parents working as recyclers (Zheng et al., 2008). Thus, not only e-waste workers or traders are vulnerable, but equally at risk are those who trade at the adjoining food market.

It is worth noting that research conducted in recent years on lead exposure through e-waste recycling has increased public health concern about the toxicity of lead at low dose. And this has supported a reappraisal of the levels of lead exposure that may be safely tolerated in the workplace (Zheng et al., 2008; Liu et al., 2011). Yet, the debate has not engaged Ghana as it has done elsewhere in China and India. Though this study did not look at the relationships between physical indices, it is well known that lead is associated with physical development of children and adults by blocking the absorption of calcium, iron and other elements, and inhibiting the synthesis and utilization of hormones (Huseman et al., 1992). Future studies should be conducted to include children and also determine the relationship between these influential factors.

In summary, our findings suggest considerable increases in exposure of e-waste and non e-waste workers to lead concentration. Yet, it is difficult to conclude on the degree of concern, because of the limited scope of the study and the fact that it did not have prior comparative data on participants' health. However, it provides a useful basis and insights into how e-waste recycling, which remains a major source of livelihood for many people, is fraught with significant health risk. The findings thus complicate the e-waste sector and raise questions about the health and safety of traders, visitors, and residents in the immediate environment, and food safety in the nearby market. Based on these possible impacts, it is necessary to increase public awareness about the effects of exposure to lead from e-waste recycling and arouse local government's interest in public health and safety, so that an infrastructure for safe management of e-waste can be established.

6.0 Stakeholders intervention and Conclusion

6.1 Existing interventions by stakeholders

The Ghanaian government, and some donor agencies and NGOs are working to address the environmental health impact of informal e-waste recycling. The occupational and environmental health Department of the Ministry of Health (MoH) states:

> *There is no work or activity without one or more hazards. The important element is to identify such hazards for elimination or control. To do so, knowledge and technology are required. ... Administrative needs cannot be overlooked like reducing hours of exposure to pollutants and encouraging use of protective wears in such working environments*.

To this extent, the ministry organised several health screening exercises for the workers at the Agbogbloshie scrap yard in 2013. Although the workers reckoned the exercise

was not targeted at e-waste related health risks, they commended the intervention in diagnosing diseases such as malaria, body aches, blurred vision, and cough. Further, the ministry supported by the Blacksmith Institute conducted epidemiological research to provide baseline information to inform policies on e-waste management (see Caravanos et al., 2011).

Furthermore, the Ministry of Environment, Science, Technology and Innovation (MESTI) in addition to its hazardous waste management bill (which includes e-waste) at the cabinet level has developed a new sanitation (2012) and climate change policy with sections focusing on e-waste management. One of its sector agencies, the Environmental Protection Agency (EPA), has provided empirical data through their numerous epidemiological studies conducted at the site. As a regulatory body, EPA has embarked on several initiatives to address the general environmental challenges of Agbogbloshie. For instance, its inter-ministerial committee on Agbogbloshie organised a multi-stakeholder meeting in August 2014 to outline a workable strategy. In the short term, a "no-burning of e-waste" intervention project was agreed to be implemented, although this seems to duplicate efforts by GreenAd to build a copper recycling facility with the same objective.

The National Youth Authority (NYA), custodian of the Agbogbloshie land, has not conducted any baseline study yet, but it has indicated that based on existing studies from their partners, they have prepared a long-term plan to develop a “Youth City” project at the Agbogbloshie area. This is expected to be a hostel facility for young people between the ages of 17 to 35 years, a recreational complex for sports, leisure and general amusement, and trading facilities with shops/stalls and sheds (which will cater for the recycling workers as well as the onion and yam traders). These projects are expected to be carried out in phases such that ongoing economic activities will not be affected.

Among the industry stakeholders, GreenAd appears to be the most trusted partner by the recycling workers at Agbogbloshie. Indeed, in January 2015 GreenAd with support by the Blacksmith Institute (and in consultation with the NYA) constructed a copper recycling centre at the site in an attempt to curb the burning activities. The effectiveness of the centre is, however, questionable at the moment as the machine needed for processing most of the copper wires is yet to be installed. Thus, the facility is not operating at full capacity and discussions on operational and financial management of the facility are also inconclusive. In the second phase of their project implementation, GreenAd is working on organising the recyclers into a cooperative (through registration with ASDA) and running business models,

which will enable recyclers to access loans and other forms of support. The projected business plans will also help recyclers maintain sustainable firms and practices. The Director of GreenAd noted in an interview that these activities are a translation of interventions enshrined in the national e-waste strategy that GreenAd prepared in consultation with EPA which are yet to be considered. Previously, GreenAd has sent some recycling workers to Sweden to learn best practices for recycling with minimal environmental impacts. They have also provided workers with nose masks and other protective equipment. According to one ASDA executive:

> *The efforts by NGOs are quite commendable compared to that of public stakeholders, researchers and the journalists. The reason is that, over the years many students, researchers, and journalists have come here to ask us about our work and the problems we face, but no intervention has come from them. They don't even come back to tell us what they have found here.*

The resentment of the executive is grounded in years of poor communication from researchers, NGOs, and journalists. Therefore, researchers and journalists, who continue to stir up public outcry over Agbogbloshie's recycling, must try to reconnect with the workers themselves; helping to coordinate public investments into the site, keeping the workers informed about all future public policy changes and ensuring that their much-needed work is safer and more prosperous.

6.2 Concluding remarks

This study examined livelihood activities and associated health impacts in Agbogbloshie scrap yard. It used interviews, focus group discussions, participatory mapping, and blood lead analysis techniques to unravel the complexity of the e-waste economy on the site. Although trade in e-waste appears economically lucrative, it also embodies significant health risks. The study shows multiple livelihood dynamics within the value chain of e-waste recycling, coherent complex internal organization, and strong linkages with ancillary businesses within the yard and formal businesses in Accra and beyond. Furthermore, we observed that each of the activities identified within the e-waste chain when nurtured consciously through stakeholder-sponsored investment programs can positively impact livelihoods and contribute significantly to overall economic growth and poverty reduction.

The findings emphasize the need to re-conceptualise e-waste recycling as a business. This claim challenges the oversimplified perspective on e-waste as a sheer movement of

materials from origins to final resting points. The normative conception of e-waste sidesteps the complex and nuanced spatial realities the recycling process entails. The complex material realities associated with e-waste were explicated in Agbogbloshie. There, e-waste recycling is seen as inserted in a chain of organized occupational wage structure. For example, collectors and scrap dealers who represent the lowest and highest segments in the e-waste economy earn a daily average income of GH¢ 25 and GH¢102 respectively. These figures are quite high by Ghanaian standards where current daily minimum wage is GH¢ 6. It suggests that an average collector for instance, earns over four times the income of a regular civil servant. This perspective calls for a more holistic financial and support system, including pricing, regulation, and the formation of cooperatives, as well as the development of commercial linkages between producers and market intermediaries for the recyclers.

Despite its economic benefits, e-waste recycling also involves significant health risks. In the analysis of BLLs, no case of elevated lead concentration was found in the sample. However, considerable rising levels of exposure of both e-waste and non e-waste workers to lead concentration resulting from e-waste activities were found. As observed in this study, the BLLs of recyclers/burners were higher than that of the different occupational categories. This suggests close connections between workers BLLs and the burning activities (during metal recovery). Beyond e-waste being a fundamental determinant, an exposure dependent relationship was found between BLL and risk factors including age, working years and hours spent at the scrap yard. For instance, BLLs in e-waste workers tend to increase with age. Also, the results further indicate that BLLs in e-waste workers correlate positively with working hours. Additionally, among all the demographic (age, gender, and residence) and social/lifestyle (smoking, alcohol intake, hand washing, and frequent changing of work clothes) factors investigated, residence and frequency of changing work clothes significantly contributed to the observed BLLs for both e-waste and non e-waste workers. Though not significant, those who drink alcohol tend to have higher lead levels in their blood compared to their smoking counterparts (who were believed to be occasional smokers).

We speculate that the BLLs in e-waste workers may be caused by direct exposure to lead during e-waste recycling while that of the non e-waste workers may be due to the lead contamination in the environment. These findings corroborate the hypothesis that participants' vulnerability to lead concentration cannot be fully accounted for through direct contact (e.g. recyclers/burners) alone, but equally through the long term exposure to

contaminated air. Accordingly, since low blood lead concentrations are inversely associated with adverse health effects - hypertension, renal disease, and neurological dysfunction - workers exposure might pose a risk for these recyclers and traders later in life. One could hypothesize that those who trade at the adjourning food market or stay at the nearby settlements, particularly children may equally be at risk. These observations provide a useful frame for further research. Workers' lead contamination prevention and controlling should thus be a long-term mission in Agbogbloshie. Although some government led initiatives have been channelled into risk assessment research, broader appreciation of e-waste lead exposure as a public health concern, national guidelines on elevated lead levels, proactive management strategy taken to minimize e-waste production, and effective protective measures for recyclers are imperative if reducing workers' BLLs is an ongoing future pursuit.

More importantly, responsible management strategies should be undertaken by policy makers to minimize e-waste shipment and generation to ensure e-waste components is easily recyclable. Stakeholders such as MESTI, MoH, and GreenAd should also appreciate the need for an integrated approach along the continuum of production, processing, and marketing while coordinating to adequately address the health implications through education and the introduction of socially acceptable and environmentally friendly technologies. To this extent, we suggest that any proposals for Ghana's e-waste management strategy should carefully consider the burgeoning informal sector before establishing a parallel system to compete with recyclers. This claim is important in order not to crush the recycling sector and switch the health issues for social ones.

The study raises several questions, which may be addressed through further research. For instance, future studies might examine the role of the local association in organizing recyclers into cooperatives, and the graduation and integration process within the e-waste economy. Future research is also required to investigate issues of value chain promotion, forging linkages between the informal and formal economies, strengthening technology transfer, branding local knowledge and ingenuity, and increasing the quality and productivity (economic margins) of recycling activities. We recommend further studies to determine the relationship between BLLs in both e-waste and non-e-waste workers and the actual lead contamination in the environment; the relationship between BLLs and possible influential factors, and the health effects of BLLs on the workers and other exposed population, particularly children.

References

Adovor Tsikudo, K.A. (2016). *Contested Natures.* forthcoming

Amankwaa, E.F. (2014a). *E-Waste livelihoods, blood lead level and sediment pollution in Ghana*. LAP LAMBERT Academic Publishing, Germany.

Amankwaa, E. F. (2014b). E-waste livelihoods, environment and health risks: Unpacking the connections in Ghana. *West African Journal of Applied Ecology* 22 (2), 1-15.

Amankwaa, E.F. (2013). Livelihoods in risk: exploring health and environmental implications of e-waste recycling as a livelihood strategy in Ghana. *Journal of Modern African Studies* 51(4): 551-75.

Amoyaw-Osei, Y., Agyekum, O., Pwamang, J., Mueller, E., Fasko, R., and Schluep, M. (2011). *Ghana e-waste country assessment*, SBC e-waste Africa Project, Accra, Ghana.

Armah, F. (2008). Local participation in water resource management: A case study of Old Fadama community, Accra, Ghana. Unpublished master's thesis, Environmental Studies and Sustainability Science, Lund University, Sweden.

Asante, K.A., Agusa, T., Biney, C.A., Agyekum, W.A., Bello, M., Otsuka, M., Itai, T., Takahashi, S. and Tanabe, S. (2012). Multi-trace element levels and arsenic speciation in urine of e-waste recycling workers from Agbogbloshie, Accra in Ghana, *Science of the Total Environment* 424: 63–73.

Asante, K.A., Agusa, T., Subramanian, A., Ansa-Asare, O.D., Biney, C.A. and Tanabe, S. (2007). Contamination status of arsenic and other trace elements in drinking water and residents from Tarkwa, a historic mining township in Ghana, *Chemosphere* 66:1513–22.

Basel Action Network (BAN). (2005). The digital dump: Exporting re-use and abuse to Africa. Basel Action Network. Available at http://www.ban.org (accessed 24 October 2005).

Basel (2010). *Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, 1989.*

Bellinger, D. (2013). Prenatal exposures to environmental chemicals and children's neurodevelopment: an update. *Safety and Health at Work* 4:1–11.

Brigden, K., Labunska, I., Santillo, D. and Johnston, P. (2008). Chemical contamination at e-waste recycling and disposal sites in Accra and Koforidua, Ghana. *Greenpeace Laboratories Technical Note*, 10: 1–23.

Canfield, R. L., Henderson, C. R., Cory-Slechta, D. A., Cox, C., Jusko, T. A. and Lanphear, B. P. (2003). Intellectual impairment in children with blood lead concentrations below 10 microgram per decilitre. *The New England Journal of Medicine* 348: 1517–26.

Caravanos, J., Clark, E., Fuller, R. and Lambertson, C. (2011). Assessing worker and environmental chemical risk at an e-waste and disposal site in Accra, Ghana. *Blacksmith Institute Journal of Health and Pollution* 1(1): 16-25.

Castree, N. and Braun, B. (2001). *Social Nature: Theory, practice, and politics*. (N. Castree and B. Braun, Eds.). Oxford, Malden, MA: Blackwell Publishers.

CDC (Centers for Disease Control). (2009). Adult blood lead epidemiology and surveillance-United States, (2005-2007). MMWR Weekly April 17, 2009/58(14):365-69.

CDC (Centers for Disease Control). (2006). Adult blood lead epidemiology and surveillance-United States, 2003-2004. MMWR, 55:876-9.

CDC (Centers for Disease Control). (1991). Preventing lead poisoning in young children. Atlanta, GA.

COHRE (2004). *A Precarious Future: The Informal Settlement of Agbogbloshie, Accra, Ghana*. Centre on housing rights and evictions (COHRE).

Cruz, P. M., Cabral, P. and Mateu, J. (2011). Mapping the Quality of life Experience in Alfama: A case study in Lisbon, Portugal. *LNCS* 6782: 269-83.

European Food and Safety Authority. (2010). Scientific opinion on lead in food. *EFSA Journal* 8(4): 1570.

Everett, C.J., Frithsen. I. and Player, M. (2011). Relationship of polychlorinated biphenyls with type 2 diabetes and hypertension. *Journal of Environmental Monitoring* 13: 241–51.

Gidwani, V. (2008). *Capital Interrupted: Agrarian Development and the Politics of Work in India*. Minneapolis and London: University of Minnesota Press.

Grant, K., Goldizen, F.C., Sly, P.D., Brune, M-N., Neira, M., van den Berg, M. and Norman, M.E. (2013). Health consequences of exposure to e-waste: a systematic review. *Lancet Global Health* 1: e350–61.

Grant, R. and Oteng-Ababio, M. (2012). Mapping the invisible and real African' economy: Urban e-waste circuitry. *Urban Geography* 33(1): 1-21.

GSS (Ghana Statistical Service) (2012). *2010 Population and Housing Census: Summary Report of Final Results*. Accra: GSS.

Guilarte, T.R, Opler, M. and Pletnikov, M. (2012). Is lead exposure in early life an environmental risk factor for schizophrenia? Neurobiological connections and testable hypotheses. *Neurotoxicology* 33: 560–74.

Ha, N.N., Agusa, T., Ramu, K., Tu, N. P.C., Murata, S. and Bulbule, K.A. (2009). Contamination by trace elements at e-waste recycling sites in Bangalore India. *Chemosphere* 76: 9-15.

Hu, H., Shih, R., Rothenberg, S. and Schwartz, B.S. (2007). The epidemiology of lead toxicity in adults: measuring dose and consideration of other methodologic issues. *Environmental Health Perspective* 115: 455–62.

Huo, X., Peng, L., Xu, X., Zheng, L., Qiu, B., Qi, Z., Zhang, B., Han, D. and Piao, Z. (2007). Elevated blood lead levels of children in Guiyu, an electronic waste recycling town in China. *Environmental Health Perspectives* 115(7): 113-17.

Huseman, C.A., Varma, M.M. and Angle, C.R. (1992). Neuroendocrine effects of toxic and low blood lead levels in children. *Pediatrics* 90: 186–89.

International Atomic Energy Agency (IAEA 452). (2011). Certified reference material- Trace elements and methyl mercury in biota. Vienna International centre, Australia. RS_IAEA_452_02.

Korrick, S.A., Hunter, D.J, Rotnitzky, A., Hu, H. and Speizer, F.E. (1999). Lead and hypertension in a sample of middle-aged women. *American Journal of Public Health* 89: 330–35.

Kosnett, M.J., Wedeen, R.P., Rothenberg, S.J., Hipkins, K.L., Materna, B.L., Schwartz, B.S., Hu, H. and Woolf, A. (2007). Recommendations for medical management of adult lead exposure. *Environmental Health Perspectives* 115(3): 463-71.

Lanphear, B.P., Hornung, R., Khoury, J., Yolton, K., Baghurst, P. and Bellinger, D.C., (2005). Low-level environmental lead exposure and children's intellectual function: an international pooled analysis. *Environmental Health Perspectives* 113: 894-99.

Lepawsky, J. (2012). Legal geographies of e-waste legislation in Canada and the US: Jurisdiction, responsibility and the taboo of production. *Geoforum* 43(6): 1194–1206.

Lepawsky, J. and Mather, C. (2011). From beginnings and endings to boundaries and edges: Rethinking circulation and exchange through electronic waste. *Area* 43(3), 242–9.

Liu, J., Xu, X., Wu, K., Piao, Z., Huang, J., Guo, Y., Li, W., Zhang, Y., Chen, A. and Huo, X. (2011). Association between lead exposure from electronic waste recycling and child temperament alterations. *NeuroToxicology* 32: 458-64.

Moore, S. (2008). The politics of garbage in Oaxaca, Mexico. *Society and Natural Resources*, 21(7): 597–610.

Moore, S. (2012). Garbage matters: Concepts in new geographies of waste. *Progress in Human Geography*, 36(6): 780–99.

Oteng-Ababio, M. and Amankwaa, E.F. (2014). The e-waste conundrum: balancing evidence from the North and on-the ground developing countries realities for improved management. *African Review of Economics and Finance* 6(1): 181-204.

Oteng-Ababio, M., Amankwaa, E.F. and Chama, M.A. (2014a). The local contours of scavenging for e-waste and higher-valued constituent parts in Accra, Ghana. *Habitat International* 43: 163-71.

Oteng-Ababio, M., Chama, M. A. and Amankwaa, E. F. (2014b). Qualitative analysis of the presence of PBDE in ashes, soils and vegetables from Agbogbloshie e-waste recycling site. *Journal of Environmental Research and Management* 5(4): 071-80.

People's Dialogue. (2010). *Housing the Masses: Final Report to People's Dialogue on Human Settlements*. People's Dialogue, Ghana, January, 2010.

Pickren, G. (2014). Political ecologies of electronic waste : uncertainty and legitimacy in the governance of e-waste geographies. *Environment and Planning A* 46(1): 26–45.

Pinto, V. N. (2008). E-waste hazard: Impending challenge. *Indian Journal of Occupational and Environmental Medicine* 12: 65-70.

Prakash, S., Manhart, A., Amoyaw-Osei, Y. and Agyekum, O. (2010). Socio-economic assessment of feasibility study on sustainable e-waste management in Ghana. Institute for Applied Ecology, Freiburg, Germany. Accessed 19 September 2014 http://www.oeko.de/oekodoc/1057/2010-105-en.pdf

Pulido, L. (2000). Rethinking environmental racism: White privilege and urban development in Southern California. *Annals of American Association of Geographers* 90(1):12–40.

Rogerson, R. (1999). Quality of life and city competitiveness. *Urban Studies* 36(5): 969-85

Seik, F. T. (2000). Subjective assessment of urban quality of life in Singapore (1997-1998). *Habitat International 24*(1): 31–49.

Sen, A. (2000). *Development as Freedom*. Oxford University Press

Stephen, O.E. (2010). Assessment of quality of life using GIS. *GIS World.* http://geospatialworld.net/Regions/ArticleView.aspx?aid=30508 (Accessed 04/08/2014).

Surkan, P.J., Zhang, A., Trachtenberg, F., Daniel, D.B., McKinlay, S. and Bellinger, D.C. (2007). Neuropsychological function in children with blood lead levels <10 microgram/dL. *Neurotoxicology* 28: 1170–77.

Tiwari, D. and Dhawan, N.G. (2014). E-waste management : An emerging challenge to manage and recover valuable resources. *International Journal of Environmental Research and Development* 4(3): 253-60

Weisskopf, M.G., Weuve, J., Nie, H., Saint-Hilaire, M-E., Sudarsky, L., Simon, D.K., Hersh, B., Schwartz, J., Wright, R.O. and Hu, H. (2010). Association of cumulative lead exposure with Parkinson's disease. *Environmental Health Perspectives* 118(11): 1609–13.

Zaid, Y.A. and Popoola, S.O. (2010). Quality of life among rural Nigerian women : The role of information. *Library Philosophy and Practice (e-Journnal).* Paper 513

Zheng, L., Wu, K., Li, Y., Qi, Z., Han, D. and Zhang, B. (2008). Blood lead and cadmium levels and relevant factors among children from an e-waste recycling town in China. *Environment Resource* 108: 15–20.

The International Growth Centre (IGC) aims to promote sustainable growth in developing countries by providing demand-led policy advice based on frontier research.

Find out more about
our work on our website
www.theigc.org

For media or communications
enquiries, please contact
mail@theigc.org

Subscribe to our newsletter
and topic updates
www.theigc.org/newsletter

Follow us on Twitter
@the_igc

Contact us
International Growth Centre,
London School of Economic
and Political Science,
Houghton Street,
London WC2A 2AE

International Growth Centre

DIRECTED BY
LSE
UNIVERSITY OF OXFORD

FUNDED BY
UKaid
from the British people

Designed by soapbox.co.uk