E-WASTE IMPORTS AND MANAGEMENT PRACTICES IN GHANA:

'A CASE STUDY OF ACCRA-TEMA METROPOLITAN AREA'

BY

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DECLARATION

I, Henry Ayikai Okine of the Environmental Science Programme, Institute for Environmental and Sanitation Studies, University of Ghana hereby declare that this thesis is the result of the research work undertaken in the Accra-Tema Metropolitan Area in the Greater Accra Region of Ghana, under the supervision of Dr. Martin Oteng-Ababio, Dr. Benjamin D. Ofori and Dr. Kwadwo Ansong Asante.

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DEDICATION

I dedicate this thesis to God Almighty for granting me the grace to reach this far in my academic pursuits, and to my lovely mum, Veronica.

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ABSTRACT

Ghana like many West African countries has become a recipient of large volumes of used electrical and electronic equipment (UEEE), popularly christened, e-waste. This study was conducted to analyse the flow of UEEE imports into Ghana, how such imports are handled and managed; and further assess the potential environmental and health challenges associated with the current management practices. The methodology involved analysis of data on the flow of used computer imports to Ghana, observations and interviews on UEEE imports handling procedures at the Tema Port. Also, heavy metals analysis of soils from control and e-waste sites, and of urine samples from e-waste workers and control group were conducted.

The results indicated that though some UEEE /e-waste imports are from developing nations, the larger share of such imports is from the developed regions, particularly Europe and North America. A partial support was thus found for the pollution haven hypothesis. Effective mechanisms for controlling and managing obsolete or non-functional UEEE import flows in Ghana are currently non-existent. Enforcement officials at the Tema port lack the requisite or adequate logistical, technical and legal capacity to effectively handle or tackle such flows.

Significantly higher Pb, Sb, As, Hg and Zn concentrations were found in soil from the e-waste recycling/disposal sites compared with those of the control site. Furthermore, significantly higher levels of Pb, Cu and Zn and Sb were found in urine of e-waste workers compared with those of the control group. This suggests heavy metal contamination of soil and exposure of e-waste workers to these metals through e-waste recycling activities which could have adverse environmental and health implications. It is recommended that urgent steps are taken to minimize the importation of non-functional UEEE to Ghana. Adequate and more efficient strategy should also be put in place to properly manage e-waste so as to protect human health and the environment.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAS:	Atomic Absorption Spectrometer
ACS:	African Coastal Services
As:	Arsenic
B/L:	Bill of lading
CEPS:	Customs, Excise and Preventive Services
Cd:	Cadmium
CFC:	Chlorofluorocarbons
C.P.C:	Customs procedure codes
CRT:	Cathode Ray Tube
Cu:	Copper
DIC:	Destination Inspection Company
ECOWAS:	Economic Community of West African States
EPA:	Environmental Protection Agency
E-waste:	Electronic waste
EEE:	Electrical and Electronic Equipment
EU:	European Union
FCVR:	Final Classification and Valuation Report
GCB:	Ghana Commercial Bank
GCMS:	Ghana Customs Management System
GCNet:	Ghana Community Network Services
GDP:	Gross Domestic Product
GPHA:	Ghana Ports and Harbours Authority
GRA:	Ghana Revenue Authority
GreenAd:	Green Advocacy

GSA:	Ghana Standards Authority
GPHA:	Ghana Ports and Harbours Authority
GAEC:	Ghana Atomic Energy Commission
GMT:	Greenwich Mean Time
Hg:	Mercury
IAEA:	International Atomic Energy Agency
IARC:	International Agency for Research on Cancer
IQ:	Intelligence quotient
QA:	Quality assurance
QC:	Quality control
IDF:	Import Declaration Form
Interpol:	International Criminal Police Organisation
ISO:	International Organization for Standardization
JPCU:	Joint Port Container Unit
Kg:	Kilogram
LCD:	Liquid crystal display
LED:	Light emitting diode
L.I:	Legislative Instrument
M.D.A:	Ministry, Department and Agency
mg:	milligram
MMIC:	Microwave frequency integrated circuit
Ni-Cd:	Nickel-Cadmium
OCED:	Organisation of Economic Cooperation and Development
ODS:	Ozone depleting substances
PAH:	Polycyclic aromatic hydrocarbon

Pb:	Lead
PCB:	Polychlorinated biphenyl
PC-boards:	Printed circuit boards
PHH:	Pollution Haven Hypothesis
PNDCL:	Provisional National Defence Council Law
POP:	Persistent organic pollutants
PENAf:	Ports Environmental Network-Africa
PUR:	Polyurethane
PVC:	Polyvinyl chloride
PTFE:	Polytetrafluoroethylene
UEEE:	Used Electrical and Electronic Equipment
WEEE:	Waste Electrical and Electronic Equipment
WSR:	Waste Shipment Regulation
Sb:	Antimony
SBC:	Secretariat of Basel Convention
TCT:	Tema Container Terminal
TCC:	Tax clearance certificate
TIN:	Tax payers identification number
TMA:	Tema Metropolitan Assembly
TV:	Television
UK:	United Kingdom
USA:	United States of America
Zn:	Zinc

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background

Electronic communication is considered inherently green since it minimizes paper waste and its associated transit (Society of Toxicology, 2012). However, rapid technological advancement has led to the generation of a constantly escalating inventory of obsolete electrical and electronic equipment that is eventually disposed of as electronic waste or e-waste (Society of Toxicology, 2012). It is estimated that globally, between 20 to 50 million tonnes of e-waste is generated every year, representing 1-3% of the world's municipal waste (UNEP, 2005; Brigden *et al*., 2008; Caravanos *et al*., 2011). E-waste is recognised as the fastest growing waste stream in the world (Nnorom and Osibanjo, 2008), with annual production rate of three to five percent (SBC, 2005 in Mohan et al., 2008; Tengku-Hamzah, 2011) which is three times faster than the general municipal waste (Puckett *et al*., 2002). This trend creates enormous management challenges to many countries across the world (Tengku-Hamzah, 2011).

E-waste has emerged as a critical global environmental health issue as it poses challenges distinct from other types of waste because of its contents (Fredholm, 2008). The challenges associated with the management of e-waste are not only due to its rapidly increasing volume of generation, but more importantly, because of its hazardous nature if not properly managed (Tengku-Hamzah, 2011). E-waste contains numerous toxic chemicals and materials, including heavy metals, such as arsenic, antimony, beryllium, cadmium, chromium, copper, lead, mercury, nickel and zinc; and organic compounds of chlorine and bromine which can pose a threat to the environment and human health (Tasaki *et al*., 2006; Brigden *et al*., 2008).

It is estimated that about 40% of all heavy metals in household waste comes from electrical and electronic equipment (EEE) (Tasaki *et al*., 2006).

However, apart from its hazardous constituents, e-waste is also known to contain precious materials such as gold, silver and platinum which can be extracted (Prakash *et. al*., 2010; Grant and Oteng-Ababio, 2012). But, it remains that, many countries across the world do not have the capacity to deal with the increasing large quantities of e-waste that they generate and its hazardous constituents in an environmentally sound manner. For example, despite the fact that metals, glass and plastic in electrical and electronic devices are recyclable, in the United States, more than 70% or 3.2 million tonnes of electrical and electronic waste stream in the United States end up in landfills (Darby and Obara, 2005).

With the environment taking centre-stage in the global development agenda, both developed and developing countries are faced with the enormous challenge of finding ways of managing their e-waste in an environmentally sound manner. In Europe for instance, laws have been introduced to regulate the use and management of hazardous substances in UEEE. Nonetheless, there is evidence that hazardous e-wastes are being transported from developed countries to various destinations in developing countries (Vasudev, 2005), where environmental regulations are relatively weak, and recycling and disposal practices often take place in largely inappropriate and unregulated manner with little or no concern for potential impacts on human health or the environment (Vasudev, 2005; Bisschop, 2012)

Studies indicate that about 50 - 80% of e-waste from the industrialized countries are exported to recycling centers in developing countries such as China, India, Pakistan, Vietnam, and the Philippines (UNEP, 2005; Ha *et al*., 2009). Recently, e-waste trade has also been increasing in countries in Africa (Schmidt, 2006; Ha *et al*., 2009). Lepawsky and McNabb (2010) however notes that, the international trade in e-waste is a more complex story than being one about 'rich' countries dumping waste in 'poor' countries. They argued that the trade in e-waste is highly regionalized, with intra-regional trade accounting for most of the total trade flows. Many researchers have made several attempts to analyse the reasons for the widespread of transnational movement of e-waste despite the existence of stringent environmental laws in developed countries and an international treaty (Basel Convention) to overcome the problem (Tengku-Hamzah, 2011).

Tong and Wang (2004) have attributed the motivation for the transnational movement of e-waste from developed to developing countries to two situations. First, the segregation and disassembly of end-of-life computers is labour intensive. Second, compliance with environmental regulations increases the cost of e-waste disposal in developed countries. Streicher-Porte *et al*. (2005) and Widmer *et al*., (2005) have also related the problem of transboundary movement of e-waste to lack of national regulation and weak enforcement of law in member countries of the Basel Convention (Tengku-Hamzah, 2011). Lepawsky and McNabb (2010) furthermore relate the issue to the loopholes in the Basel Convention, such as allowance for transboundary movement of e-waste for reuse or recovery through recycling (Tengku-Hamzah, 2011).

Ghana, like other West African countries, have become one of the major destination for e-waste globally (Asante *et al*., 2012; Otsuka *et al*, 2012), receiving large volumes of obsolete UEEE imports mostly from Europe and North America (Amoyaw-Osei *et al*., 2011; Asante *et al*., 2012). The volume of e-waste imports is difficult to determine, because the declaration of it is carried out under a wide variety of (wrong) labels, ranging from 'used or second hand goods', 'household goods', 'goods for charity', 'mixed equipment', among others (SBC, 2011). As indicated by Frandsen *et al*. (2011), more than 600 pieces of 40-foot containers containing large volumes of UEEE are continually shipped to the Port of Tema each month.

Bisschop (2012), points out that, much of the EEE transported to developing countries never makes it to second hand market and is dismantled to extract the raw materials. Though this situation has resulted in an important informal industry that recycles or reprocesses e-waste and extracts the valuable metals for sale, it has also contributed to an uncontrollable emergence of e-waste scrap yards/dump sites in Ghana where recycling occurs under precarious conditions, releasing toxic substances like mercury, arsenic and lead into the air, water and soil, thus posing risks to human health and environment (Brigden *et al*., 2008; Amoyaw-Osei *et al*., 2010; Oteng-Ababio, 2011; Asante *et al*., 2012; Otsuka *et al*., 2012).

This therefore calls for a continuous and extensive research into the extent of the Ghanaian e-waste management situation in order to adequately address the existing management challenges.

1.2 Problem Statement

The cost of managing e-waste in developed countries is high compared to developing countries. As a result, developing countries like Ghana have become final destinations for used or obsolete electrical and electronic equipment transported from industrialized countries. Studies indicate that, due to the inability of many Ghanaians to afford brand new products, large consignments of used and out-dated electrical and electronic products discarded mainly in Europe and North America are shipped to Ghana (Amoyaw-Osei *et al*., 2011). Some of the products such as computers and accessories enjoy a free-import duty regime, thus, further boosting the import trade (Amoyaw-Osei et. al., 2011; Grant and Oteng-Ababio, 2012).

As at April 2014, Ghana has no specific national legislation restricting the importation of UEEE and or the disposal / recycling of e-waste except for the LI 1932 (2008) which bans the importation and sale of used air conditioners, refrigerators, refrigerator-freezers and freezers among others to Ghana. Moreover, though the Basel Convention, which establishes the framework for the transboundary movement of hazardous waste including e-waste from developed to developing member countries, has been ratified by Ghana since 2005, its provisions are yet to be transposed into national laws.

Consequently, consignments of e-waste could enter through the various ports of entry in Ghana under the guise of second hand electrical and electronic equipment for reuse, without restriction or detection, at the present (Amoyaw-Osei *et. al*., 2011). Very few researchers have attempted to analyse the flow of UEEE imports to Ghana (Amoyaw-Osei *et al*., 2011; Grant and Oteng-Ababio, 2012; Bisschop, 2012), and as to how such imports are being handled particularly by regulatory authorities at the sea-ports of entry in Ghana remains missing in many of the few available literature on e-waste.

Though the importation of UEEE offers most Ghanaians the opportunity to acquire and use these appliances, most of such imports are eventually disposed of as waste within a year or two of arrival, due to their relatively shorter useful lifespan (Amoyaw-Osei *et al*., 2011). Moreover, about 10 - 20% of UEEE imports are virtually non-functional on arrival and are sent directly to the scrap yards/dump sites, thus, adding to internally generated e-wastes (Amoyaw-Osei *et al*., 2011; Amoyaw-Osei and Pwamang, 2011). Therefore, just like other developing nations such as China, India and Nigeria, Ghana is faced with the 'double burden' of managing not only its rapidly growing domestic e-waste, but also the alarming amounts of obsolete and/or near end-of-life UEEE imports from other countries, especially from the developed regions.

This situation has led to a booming informal e-waste collection and recycling business (Prakash *et. al*., 2010; Amoyaw-Osei *et al*., 2011; Oteng-Ababio, 2011) as there is currently no well-established national formal e-waste management system in place. Nevertheless, e-waste is known to contain both beneficial and toxic substances and hence requires environmentally sound management. Therefore, how is e-waste being managed by the informal sector, and what are the environmental and health challenges associated with the current management practices in Ghana?

Available literature on the environmental and health implications of e-waste management in Ghana is limited. Studies indicate that though the management of e-waste has become a means of livelihood for many people in the informal sector (Oteng-Ababio, 2011; Prakash *et al*., 2010), the existing e-waste management system in Ghana is characterized by processes that can expose workers to toxins, degrade the local environment and inefficiently recover resources (Bisschop, 2012; Asante *et al*., 2012; Brigden *et al*., 2008).

For example, informal e-waste recyclers in areas such as Agbobgloshie and Ashaiman, and other localities in Ghana, employ crude recycling methods including the open burning of plastic coated wires and cables, and breaking the Cathode Ray Tube (CRT) of monitors with stones and chisels for the recovery of valuable raw materials such as copper and steel for sale (Prakash *et al*., 2010; Brigden *et al.*, 2008). Often, insulating foam, primarily polyurethane (PUR), from obsolete refrigerators, and automobile tyres, are used as co-fuels to sustain the fires used for burning cooling grills of air conditioners (Prakash *et al*., 2010; Brigden *et al.*, 2008). The residual non-valuable e-waste fractions are either burnt or disposed on land and / or in nearby water bodies (Prakash *et al*., 2010; Brigden *et al*., 2008).

These rudimentary modes of e-waste management can release highly toxic chemicals including lead, cadmium and mercury to the atmosphere and soil which may leach into waterways and food sources, and expose the general population, including generations to come, to highly toxic e-waste related mixtures through inhalation, contact with soil and dust, and oral intake of contaminated locally produced food and drinking water (Frazzoli *et al*., 2010). Thus, waste which could be safely disposed of or recycled now becomes a hazard, presenting manifold impacts on the environment, local communities and the economic system in general (Oteng-Ababio, 2010; Brigden *et al.*, 2008).

1.3 Objectives

The overall objective of this study was to analyse the flow of UEEE imports into Ghana and how such imports are handled and managed, and assess the potential environmental and health challenges associated with the current management practices.

Specifically, the study sought to achieve the following objectives:

1. To determine the origins of used electrical and electronic equipment imports to Ghana;
2. To examine how used electrical and electronic equipment imports are handled at the port of Tema;
3. To undertake a comparative analysis of heavy metals in soils at the e-waste recycling/dump sites at Agbogbloshie, Ashaiman and Tema;
4. To analyse the concentrations of heavy metals in urine samples from e-waste workers in the Accra-Tema Metropolis; and
5. To give recommendation for policy consideration to improve e-waste management and control in Ghana.

1.4 Research Questions

Against the background of the problem statement and objectives above, the research questions are stated as follows:

1. From which main countries are UEEE shipped to Ghana?
2. What are the characteristics and types of UEEE imports?
3. How are UEEE imports being handled in the Tema Port?

4. What are the environmental and health challenges associated with the current e-waste management practices?
5. How significantly different are heavy metal levels in soils at e-waste recycling sites in the Accra - Tema Metropolis?
6. How significantly different are heavy metal levels in urine of e-waste workers in the Accra - Tema Metropolis?
7. How well does the pollution haven hypothesis apply to the e-waste problem in Ghana.
8. What can be done to improve import control and management of e-waste in Ghana?

1.5 Hypotheses

The hypotheses for this study are stated as follows:

1. Ghana is becoming a pollution haven for e-waste.
2. Urinary metals levels of informal e-waste workers in the Accra-Tema Metropolitan Areas are related to their e-waste processing activities.
3. Crude e-waste management practices lead to significant heavy metals contamination in soil at recycling sites.

1.6 Justification

One increasing crucial global environmental issue today is the management of waste, which is becoming more challenging and complex than before due to the emergence of new kinds of waste, like e-waste. E-waste has the characteristics of causing gargantuan adverse environmental and health effects if not managed properly. Thus, there is a pressing need for in-depth studies on its management to safeguard sensitive ecosystems and living resources.

Every day, thousands of used electrical and electronic equipment such as computers, TVs and mobile phones are being shipped from other countries to Ghana. Some of these imported devices happen to be in good working conditions, others can be repaired and reused, but a about 10% (Amoyaw-Osei *et al.*, 2011) are also damaged beyond repairs and are thus creating e-waste (Amoyaw-Osei *et al.*, 2011). As there are no well-established formal e-waste management systems in the country, majority of these imported e-waste could only flow into the ill-equipped informal recycling sector (Wang, 2009), where they are subjected to crude recycling and disposal methods, endangering human health and the environment. Thus, the importation, coupled with the existing uncoordinated and improper management of e-waste system in Ghana is exacerbating the solid waste situation in the country.

It is therefore timely and important that this study on e-waste imports and management is conducted as it will help increase the awareness of Ghanaians on the flow of e-waste and the environmental and health challenges associated with the current management practices, and provide suitable policy recommendation for improved e-waste management and control in Ghana. Furthermore, this study will contribute to the existing but limited literature on the e-waste situation in Ghana, particularly in the Accra - Tema Metropolitan Area of the Greater Accra Region of Ghana. Finally, this research will also contribute to growing studies on the Pollution Haven Hypothesis (PHH).

1.7. Summary

This chapter lays the foundation for this thesis. It first gives an introductory overview of the global problem of e-waste, outlines the reasons for the transboundary shipments of e-waste to developing countries and briefly points out the benefits and challenges associated with e-waste management in Ghana. It then presents the research problem followed by the objectives, research questions and hypothesis for the research before detailing the significance for this research study. On this basis the study proceeds with a review of relevant literature in the next chapter.

CHAPTER TWO

LITERATURE REVIEW

2.1. Introduction

The introductory chapter set the stage for this study by highlighting the research problem and questions among other remarks. This chapter reviews existing literature to support and identify gaps for this thesis. Present in this literature review are definitions, composition and toxicity of e-waste as well as an overview of current body of knowledge on e-waste generation and current management practices in Ghana. The chapter further outlines the county's policy frameworks and international legislations related to e-waste shipments and management. Also included in this chapter is an overview of the theoretical framework for this research work.

2.2. What is Electronic Waste?

2. 2.1. E-waste Definition and Composition

There are various definitions for e-waste. For instance, e-waste is interpreted in Ghana's 2011 draft bill on Hazardous and Electronic Waste Control and Management as 'discarded electronic equipment inclusive of all components, sub-assemblies and consumables which are part of the product at the time of discarding'. Furthermore, according to the Swedish Environmental Agency (2011), e-waste is a generic term comprising all electrical and electronic equipment (EEE) that have been disposed of by their original users, and includes everything from large household appliances, such as refrigerators, microwave ovens, television sets, and computers, to hand-held digital apparatuses, cell phones and toys.

Within the EU the term WEEE (Waste Electrical and Electronic Equipment) is commonly used instead of e-waste to refer to end-of-life and disposed electrical and electronic equipment (Tengku-Hamzah, 2011). WEEE is understood in the EU under the Directive on Waste Electrical and Electronic Equipment (Directive 2002/96/EC, Article 3(b)) and the Directive on Waste (Directive 75/442/EEC, Article 1(a)) as 'any electrical and electronic equipment (including all components, subassemblies and consumables which are part of the product at the time of discarding) which the holder discards or intends to or is required to discard'.

Moreover, according to the Secretariat of the Basel Convention (SBC (2011), used electrical and electronic equipment (UEEE) would normally be considered to be e-waste if it falls under the following conditions:

1. The equipment is not complete - essential parts are missing and the equipment cannot perform its essential key functions;
2. It shows a defect that materially affects its functionality and fails relevant functionality tests;
3. It shows physical damage that impairs its functionality or safety, as defined in relevant standards;
4. The protection against damage during transport, loading and unloading operations is inappropriate, e.g. the packaging or stacking of the load is insufficient the appearance is particularly worn or damaged, thus reducing the marketability of the item(s);
5. The item has among its constituent part(s) hazardous components that are required to be discarded or are prohibited for use in such equipment under national legislation;
6. There is no market for the equipment;
7. It is destined for cannibalization (to gain spare parts);
8. The price paid for the items is significantly lower than would be expected from working equipment intended for re-use; or
9. It is destined for disposal operations.

This SBC definition for e-waste has been adopted for this study.

E-waste is made up of a mixture of metals, mainly copper, aluminium and iron - which are attached to, covered with or mixed with various types of plastic and ceramic (Hoffmann, 1992). It is non-homogeneous and complex in terms of its materials and components (Juan, 2009), some of which are harmful and others considered a resource (e.g. as platinum, silver, and gold). Widmer *et al*., (2005) found that there over thousand chemical substances present in e-waste. The composition of e-waste (including the type and percentage of materials) varies depending on the type of equipment (Tengku-Hamzah, 2011).

E-waste has emerged as a significant environmental issue due to its toxicity (Widmer *et al*., 2005). The components of e-waste including motherboard, contains several organic and inorganic compounds which are of environment and health concern. The organic e-waste compounds include various brominated flame retardants, brominated and chlorinated dioxins (PCDD/Fs and PBDD/Fs), brominated and chlorinated benzenes and phenols, polychlorinated biphenyls (PCBs) and naphthalenes (PCNs), polycyclic aromatic hydrocarbons (PAHs), nonylphenol, organophosphorus flame retardants, phthalate esters and freons. Inorganic compounds in e-waste include antimony, arsenic, asbestos, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, tin, yttrium, and zinc (Swedish Environmental Protection Agency, 2011). These compounds are of concern because some are very toxic and others are very abundant in e-waste.

Other discrete chemicals present in e-waste include liquid crystals from liquid crystal displays (LCDs), toner dust from toner cartridges and nanoparticles from various products. The components and materials that are of most concern are: printed circuit boards (PC-boards), batteries, cathode ray tubes (CRTs), LCDs, plastics, PCB-containing capacitors, equipment containing freons, toner cartridges and various mercury containing components

(Swedish Environmental Protection Agency, 2011). The adverse health effects of major hazardous substances in e-waste are presented in Table 2.1 below.

Table 2.1: Some Hazardous substances in e-waste and their effects on health

Substances/conta-minants	**Use in electrical and electronic devices**	**Adverse health effect ***
Copper (Cu)	Wiring [1]	May damage liver, kidney and nervous system, and affecting protein metabolism in the brain causing Alzheimer disease.
Nickel (Ni)	Batteries	An uptake of too large quantities of nickel may cause cancer of the lung, nose, larynx and prostate, dizziness, respiratory failure such as asthma and chronic bronchitis, birth defects, and allergic reactions such as skin rashes.
Lithium (Li)	Batteries	Corrosive to the eyes, skin and respiratory tract.
Chromium (Cr)	Data tapes and floppy disks.[1]	Irritates eyes, skin and mucous membranes and DNA damage
Lead (Pb)	Solder [2], CRTs, batteries[1]	Damages the central and peripheral nervous system, kidney and endocrine system.
Cadmium (Cd)	Batteries, toners, Plastics [1]	Affects the kidneys, cardiovascular system, bones and testicular function, and damaging the DNA.
Mercury (Hg	Fluorescent lamps, batteries, switches[1], circuit board, semiconductors.	Toxic to lungs, kidney, nervous system and digestive system.
Barium (Ba)	Getters in CRTs	Swelling in the brain, muscle weakness and damage to the heart, liver and spleen.
Beryllium (Be)	Silicon-controlled rectifiers[1]	Lung and skin disease.
Aluminium (Al)	Chips, data storage disks	Affects brain and kidneys and may be associated with Alzheimer and Parkinson disease.
Antimony	Flame retardants[3]	Affects cardiovascular system, stomach, joints, muscles and bones.

*Sources: *Sarkar (2008), [1] Robinson (2009), [2] Kang and Schoenung (2005), [3] Ernst et al. (2003), Tengku-Hamzah (2011).*

Hazardous substances in e-waste, according to Tengku-Hamzah (2011), may be released to the environment by way of improper disposal (where e-waste is commonly disposed of together with municipal solid waste and ends in non-hazardous landfill or being incinerated; indiscriminate dumping) and dismantling and recovery practices (open burning and acid baths). Furthermore, hazardous substances have the potential to enter the environment through possible leakage in the process of movement of e-waste from one country to another.

2.3. Hazardous Heavy Metals in E-waste

Humans have used heavy metals for thousands of years for several purposes, including usage in some electrical and electronic components. Heavy metals such as mercury, arsenic, lead, cadmium, antimony, copper and zinc have known uses in EEE and therefore could be present in e-waste.

Lead

Lead is widely used in electric and electronic products, ranging from printed circuit boards, batteries to cathode ray tubes and as stabilizers in PVC cables, and is mainly recovered by manually de-soldering the components of e.g. printed circuit boards (Wang *et al*., 2009). Although lead is not very mobile in soil, lead may enter surface waters as a result of the erosion of lead-containing soil particles and the dumping of waste containing lead products such as CRT glass. Incineration, can also result in release of lead to the air as in the ash produced (Allsopp *et al*., 2001 as cited by Brigden *et al*., 2008). Exposure to lead occurs mainly through inhalation of dust and air and ingestion of foodstuffs, water and dust (UNEP, 2010). Lead is accumulated in bone through repeated exposures and may serve as a source of exposure later in life.

Lead is not required for human health, and is highly toxic to humans, even at low exposure levels (Bellinger & Dietrich 1994; ATSDR, 2007; Brigden *et al*., 2008). It has adverse effects in multiple organs and can cause neurological, cardiovascular, renal, gastrointestinal, haematological and reproductive effects (UNEP 2010). Lead exposure in children is of particular concern as it is linked to a lower intelligence quotient (IQ), behavioural effects and learning disabilities (Brigden *et al*., 2008; UNEP 2010). Majority of adult lead poisoning cases are occupational (Horne and Gertsakis, 2006).

Cadmium

The use of cadmium within electrical and electronic products includes use as stabilizers in PVC formulations, as a phosphor coating in cathode ray tubes (CRTs) (Zheng *et al*., 2008; Brigden *et al*., 2008). It is also used in switches, folder joints and rechargeable nickel-cadmium (Ni-Cd) batteries (Matthews 1996; OECD 2003; Brigden et. al., 2008). Cadmium is released by various natural and anthropogenic sources (such as incineration and breaking of CRT glass) to the atmosphere. Cadmium released to the atmosphere can deposit to land and aquatic environments, and some cadmium released to soil over time will be washed out to the aquatic environments. Exposure to cadmium can occur occupationally through inhalation of fumes or dusts containing cadmium and its compounds, or through environmental exposures, mainly diet (UNEP 2010; Heo and Lee, 2013).

Cadmium is extremely toxic to plants, animals and humans, having no known biochemical or nutritional function (ATSDR 1999; WHO 1992 as cited by Brigden *et al*., 2008). Cadmium is a cumulative toxicant and the kidney is considered the critical target organ, for both the general population and occupationally exposed populations (UNEP, 2010). Low levels of cadmium exposure was associated with renal damage and once thought to be mostly an occupational hazard (Bressler *et al*., 2004; Zheng *et al*., 2008), but attention has now focused on the general population (Zheng *et al*., 2008). Cadmium is also absorbed in the body by inhaling air which is polluted by environmental tobacco smoke, house dust, and industrial emissions (Satarug *et al*., 2000; Zheng *et al*., 2008).

Mercury (Hg)

Mercury is used in lighting device that illuminate flat screen displays, and has also been used in switches and relays of older mainframe computers. Some older computer may contain batteries containing mercury (OECD, 2003; Swedish Environmental Protection Agency, 2011). Anthropogenic releases of mercury to the environment can occur as a result of the dismantling, and combustion or landfilling of e-waste such as flat screen displays (Swedish Environmental Protection Agency, 2011). The most significant releases of mercury pollution are emissions to air, but mercury is also released from various sources directly to water and land (UNEP, 2002). Human exposure to mercury can result from a variety of pathways, including, but not limited to, consumption of fish, and inhalation of mercury vapour or dust (UNEP, 2002). Mercury has no biochemical or nutritional value, and its compounds are highly toxic and accumulative, especially to developing nervous system (UNEP, 2002).

Arsenic (As)

Arsenic is mainly found in the form gallium arsenide in electrical and electronic equipment, and used in devices such as microwave frequency integrated circuits (MMICs), infrared light emitting diodes (LEDs), laser diodes and solar cells (Flora 2000; Uryu *et al*., 2003; Swedish Environmental Protection Agency, 2011). Contaminated soil may be a potential source of arsenic exposure (WHO, 2001). Smokers are exposed to arsenic by the inhalation of mainstream cigarette smoke (http://www.who.int). Soluble inorganic arsenic is acutely toxic, and ingestion of large doses leads to gastrointestinal symptoms, disturbances of cardiovascular and nervous system functions in humans, and eventually death (WHO, 2001). The International Agency for Research on Cancer (IARC) has classified arsenic and arsenic compounds as carcinogenic to humans.

Antimony (Sb)

Antimony is used in the manufacture of lead acid starter batteries, semiconductors , flame retardant formulations in plastics (antimony trioxide), and can occur as a component of electrical solders as well as in CRT glass (Swedish Environmental Protection Agency, 2011; Kentner *et al*., 1995; Brigden *et al*., 2008). Antimony is released to the environment from natural sources and industrial sources (ATSDR, 1995). Industrial activities such as mining and smelting of mineral ores, and the use of antimony containing products are the main sources of antimony in the environment (Itai *et al*., 2014).

Since antimony is found naturally in the environment, the general population is exposed to low levels of it every day, primarily in food, drinking water, and air. Workers processing or using antimony may be exposed to higher levels (ATSDR, 1995) as a result of fumes or dust inhalation or dermal contact with soil at hazardous waste sites (ATSDR, 1995; Brigden *et al*., 2008). Antimony is a human carcinogen and known to cause liver, skin, and respiratory and cardiovascular diseases (Itai *et al*., 2014). The WHO provisional tolerable daily intake for antimony is 6 µg/kg bw/day.

Copper

Copper is a key component in electric wires and cables and is primarily recovered by open burning (Wang *et al., 2009*). Copper can be released into the environment by both natural sources and human actions. Anthropogenic releases of copper into the environment can come from various sources including, smelting, domestic and industrial wastewaters, steam electrical production, incineration and landfilling of copper-containing products which includes electronic wastes (http://www.atsdr.cdc.gov/toxprofiles/tp132-c1.pdf). Copper is an essential trace element that can cause symptoms of deficiency and can be toxic when exposures exceed physiological needs. Human exposure to these elements includes the inhalation of fumes or the particulates of these elements, ingestion of food, water or dust, and dermal contact with contaminated soil or water (WHO, 2003).

Exposure to higher doses of copper can cause adverse health effects, including gastrointestinal distress (nausea, vomiting, abdominal pain), respiratory tract irritation, liver and kidney damage, anaemia, immunotoxicity, and developmental toxicity (Swedish Environmental Protection Agency, 2011) and can even cause death under extremely high ingestion (CDPHE, 2008; Amfo-Otu *et al*., 2013).

Zinc

Zinc, found in the form of zinc sulphide is used in luminescent pigments on the interior of CRT screens (Swedish Environmental Protection Agency, 2011). Natural background total zinc concentrations in soils are usually 10–300 mg/kg dry weight (dw) (WHO, 2003). The disposal of zinc-bearing waste may increase zinc concentrations in soil (WHO, 2003). The primary source of human exposure to zinc is food, although oral exposure can become excessive through non-dietary sources.

Zinc is an essential trace element that can cause symptoms of deficiency and can be toxic when exposures exceed physiological needs (WHO, 2003). Occupational exposure to high levels of zinc oxide and/or nonferrous metals is associated with metal-fume fever, which is usually a short-term, self-limiting syndrome, characterized by a variety of symptoms including fever, chills, dyspnoea, nausea and fatigue. The condition is generally severe but transient, and individuals tend to develop tolerance (WHO, 2003). In healthy humans, only small amounts (≈ 0.5 mg/day) of Zn are excreted via urine (Swedish Environmental Protection Agency, 2011).

2.4. Overview of the E-waste Scenario in Ghana

This section gives a general overview of the existing e-waste situation in Ghana. It is divided into two sub-sections. First, an overview of the generation of e-waste is given, and second, the current e-waste management practices are highlighted.

2.4.1. E-waste Generation in Ghana

In line with present trends in the global electronic and information age, the demand and consumption of electrical and electronic equipment such as computers and mobile phones continue to increase daily in Ghana (Amoyaw-Osei *et al*., 2011). However, due to the rather very few number of existing locally based EEE-assembling companies, majority of these EEE in demand and use are imported from other countries (mainly in Europe, North America and Asia) (Amoyaw-Osei *et al*., 2011). The level of demand has resulted in an alarming in-flux of EEE into the country, majority of which are second-hand products - since of most Ghanaians are not able to afford brand new EEE which are relatively expensive (Amoyaw-Osei and Pwamang, 2011; Grant and Oteng-Ababio, 2012).

Notably, the importation of some of the EEE such as computers enjoy a free-import duty regime in Ghana, thus, further enhancing the import trade (Amoyaw-Osei *et al*., 2011). Oteng-Ababio (2012) explains that, the strategic decision of the government in 2004 to tax exempt the importation of used computers to make the product easily accessible and affordable, has since resulted in a phenomenal increase in the importation of used computers, from a total of 1.3 million kilograms in 2004, to 3.6 million kilograms in 2008. This has contributed to a highly booming second-hand EEE import business involving both formal and informal sectors.

However a significant proportion of these UEEE imports are old, near or at end-of-life and are sooner or later discarded as e-waste, thus leading higher e-waste generation per year

(Amoyaw-Osei and Pwamang, 2011; Oteng- Ababio, 2012). While about 10-20% of used EEE imports are already dysfunctional on arrival, another 20% have a short lifespan of less than years (Amoyaw-Osei *et al.*, 2011). Thus, apart from domestic sources, a considerable volume of the e-waste in Ghana is from imported sources. Estimates indicate that 171,000 tonnes of e-waste was generated in Ghana in 2009 (Amoyaw-Osei *et al*., 2010). Despite the existing large stocks and the ever increasing e-waste generation in Ghana (Amoyaw-Osei *et al*., 2010), no effective management mechanism or specific legislation for its import control have been institutionalised by the Government of Ghana.

2.4.2 Current E-waste Management Practices in Ghana

The e-waste sector in Ghana employs thousands of Ghanaians as well as multi-nationals from other countries including Nigerians, Togolese, Indians and Chinese (Amoyaw-Osei *et al.,* 2011; Oteng-Ababio, 2012; Prakash *et al*., 2010). As a result of government's failure to provide e-waste disposal facilities and formal management systems for its environmentally sound management, the informal sector have shown absolute dominance in the management of e-waste in Ghana. It is estimated that a total of between 6,300 – 9,600 people work in the informal e-waste sector in the country, with a dependent population of between 121'000 – 201'600 (Prakash *et al*., 2010; Amoyaw-Osei *et al.*, 2011).

Informal e-waste operations occur in different parts of the country, but the hub of recycling operations is in the Greater Accra Region at the scrap yards at Agbogbloshie as well as at Gallaway all in the Accra metropolitan area and Ashiaman, in the Tema Metropolis (Prakash *et al*., 2010). Oteng-Ababio (2011) studied informal e-waste management practices at Agbogbloshie and found that the e-waste economy in this area is highly stratified and made up four main activities which are: collection, recycling, repair and refurbishment, and trading of metals.

The collection of e-waste in the informal sector is done by informal collectors also known as scavengers who normally execute door-to-door collection and purchase obsolete EEE from private, corporate and institutional consumers at relatively low prices and bring them to the scrap yard (Prakash *et al.*, 2010, Amoyaw-Osei *et al*., 2011; Oteng-Ababio, 2011). Often, the informal collectors do not pay anything for these items as they find them dumped at street corners and even at the dumpsites by importers. Collectors sometimes travel long distances and also sift through waste bins, visit landfills and other waste dumping grounds for e-waste (Amoyaw-Osei *et al*., 2011; Prakash *et al.*, 2010).

Normally, the collection of e-waste is undertaken with the most rudimentary technologies like moving around with a pushcart, sacks, and basic tools (e.g. hammer, wrench, screwdriver (Grant and Oteng-Ababio, 2012). In several cases, collectors also engage in e-waste dismantling and metal recovery including the burning of cables and wires to liberate copper for sale (Prakash *et al*., 2010, Oteng-Ababio, 2011). Currently, about 90% of e-waste in Ghana is collected by the informal sector (Rufener, 2012). Prakash *et al*. (2010) in their socio-economic survey found that monthly incomes of e-waste collectors were between US$ 70 and 140, refurbishers earned between US$ 190 to 250, and recyclers between US$ 175 to 285.

Refurbishers / repairers are those that render the service of getting non-functioning EEE into functioning. Refurbishers transform old/non-functioning products by replacing defective components. They engage in cleaning and repairing activities in order to make the refurbished product more appealing and affordable to the majority of the Ghanaian populace (Oteng-Ababio, 2011).Informal e-waste recycling in Ghana is conducted by scavengers and dismantlers. The main informal e-waste recycling activity in Ghana is the manual dismantling of all types of e-waste and scrap, and the recovery of valuable metals such as copper, iron and aluminium, using simple tools like hammers, heavy metal rods and chisels (Prakash *et al.*, 2010; Amoyaw-Osei *et al*., 2011).

Copper cables are openly burnt nearby to remove the plastic casings. Insulating foam from obsolete refrigerators, primarily polyurethane and/or old car tyres are used as main fuels to sustain the fires (Brigden *et al*., 2008; Prakash *et al.*, 2010; Amoyaw-Osei *et al*., 2011). Monitor screens and other non-valuable as well as hazardous fractions including plastic casings of all types, capacitors, and dry batteries are not recovered, but are usually disposed of at the adjacent dump site, and the accumulated waste may eventually be burnt get reduce at the dumpsite (Prakash *et al*., 2010; Amoyaw-Osei *et al*., 2011).

The recovered fractions, such as ferrous metal, aluminium and copper are primarily sold to industries in Tema or to private businesses for export. Leaching of printed wiring boards is not yet a practice in the Ghanaian e-waste sector (Prakash *et al*., 2010; Amoyaw-Osei *et al*., 2011). Studies in recent times have revealed that almost all of the annual volume of e-waste (171,000 tonnes) handled by recyclers in 2009, which came directly from consumers, from consumers via communal collection, from consumers through repairers and directly from 'waste' imports, was handled by the informal recyclers (Amoyaw-Osei *et al.*, 2010). Between 10,000 and 13,000 metric tons of e-waste are treated annually in Ghana by the informal sector (Prakash *et al.*, 2010).

Grant and Oteng-Ababio (2012), in their study at Agbogbloshie found that the main tasks of Scrap dealers' are to gather and distribute various waste components. Some goods are moved into other markets, and some components are distributed through their agents (middlemen), who in turn move them to other merchants / companies. Components such as circuit boards (ground into a fine powder) and copper were shipped directly to Asian countries (especially China and India) by local scrap dealers and/or by Tema agents. The Scrap dealers have led the way in institutionalizing a professional association by establishing a voluntary association, the Greater Accra Scrap Dealers Association (Grant and Oteng-Ababio, 2012). Middlemen are said to interface with traders coming to the market to purchase or sell e-waste items (Grant and Oteng-Ababio, 2012). They comprise "well-seasoned individuals" with strong ties to circuits above and below them. Some work with scrap dealers and others, with various participants in the e-waste circuit (Grant and Oteng-Ababio, 2012).

The informal e-waste sector is mainly male dominated (Prakash *et al*., 2010; Oteng-Ababio; 2011; Amoyaw-Osei *et al*., 2011; Caravanos *et al*., 2013). A number of studies have revealed that majority of the people engaged in e-waste collection and recycling operations at Agbogbloshie are mostly youth from the Northern parts of the country, and have low levels of education (Prakash *et al*., 2010; Amoyaw-Osei *et al*., 2011; Oteng-Ababio, 2011; Caravanos *et al*., 2013). Most of the people employed in the e-waste recycling sector are aged 14 to 40 years and work for 10 to 12 hours per day, i.e. 300 to 360 hours per month (Prakash *et al*., 2010). Their main motivation for involving themselves in the e-waste business is the likelihood of making a living from the recovery and sale of some of the valuable e-waste materials such as copper, aluminium and iron (steel) by using simple tools and rudimentary methods (Brigden *et al*, 2008; Prakash *et al*., 2010; Amoyaw-Osei *et al*., 2011; Oteng-Ababio, 2011).

However, as noted by Prakash *et al*. (2010), although end-of-life treatment operations of e-waste lead to further employment and income opportunities for a large group of people, they are also associated with severe environmental and health hazards, hence diluting the overall potentials and benefits to a large extent. The crude recycling practices employed by informal e-waste workers at Agbogboshie, Koforidua, and other parts of Ghana, such as the open burning of e-waste and breaking of CRT-monitors to recover valuable materials like copper and steel, leads to the release of significant levels of toxic metals and other hazardous compounds into the environment (air, soil and water body) and posing serious health hazards to workers and people living within the vicinity(Brigden *et al*., 2008; Asante *et al*., 2012; Caravanos *et al*., 2013).

One study found that the formal e-waste recycling sector in Ghana is still in its infancy (Amoyaw *et al*., 2011; Rufener, 2012). Formal recyclers are companies or organizations that have acquired an environmental operation permit from the Ghana EPA. They dismantle, separate fractions and recover valuable materials from e-waste, but are also responsible for the environmentally sound treatment of the hazardous fractions (Amoyaw *et al*., 2011). One of the very few known formal e-waste recyclers in Ghana is City Waste Recycling Limited, which started its e-waste operations in 2010, and is presently engaged in the collection of e-waste from companies and institutions for dismantling into various fractions for sale (Rufener, 2012). Other private companies such as the Zoomlion Ghana limited, which is Ghana's current leading domestic waste management company, have also revealed their intentions to enter into full scale e-waste collection and recycling operations soon (Rufener, 2012).

2.5. Legal and Regulatory Frameworks Related to E-Waste Flow and Management

This section outlines Ghana's legal and policy framework as well as, international treaties or conventions that are applicable to e-waste. An overview of the European legislations on e-waste is also given in this section.

2.5.1 National Policies and Legislations

The relevant national environmental and other statutory laws and regulations related to the importation and management of e-waste include:

The 1992 Constitution of the Republic of Ghana; Environmental Protection Agency Act, 1994 (Act 490); the Environmental Assessment Regulations, 1999 (L.I. 1652); the Management of Ozone Depleting Substances and Products Regulations, 2005 (L.I. 1812); the Customs, Excise and Preventive Service (Management) Law 1993 (PNDCL 330); the Export and Import Act, 1995 (Act 503); the Energy Efficiency Regulations, 2008; and the Draft Bill on Hazardous and Electronic Waste Control and Management, 2011.

The 1992 Constitution of the Republic of Ghana

The 1992 constitution of Ghana, which came into force on 7th January 1993, is the fundamental law of Ghana and provides the foundation on which all other laws stand. Within the directive principles of State policy, the Constitution has a provision on environmental protection and management. Article 36(9) of the constitution states that "the State shall take appropriate measures needed to protect and safeguard the national environment for posterity; and shall seek cooperation with other states and bodies for purposes of protecting the wider international environment for mankind". Furthermore, Article 41(k) in Chapter 6 of the constitution of Ghana requires that all citizens (employees and employers) protect and safeguard the natural environment of the Republic of Ghana and its territorial waters.

The Constitution has relevance to this study because it warrants that the management of e-waste by conducted relevance of the Constitution to e-waste management is that it enjoins every citizen including e-waste workers as well as regulatory agencies to ensure environmentally sound management of e-waste.

The Environmental Protection Agency Act, 1994 (Act 490)

The Environmental Protection Agency Act, 1994 (Act 490) established the Environmental Protection Agency, with the mandate to regulate, coordinate, manage and protect the environment. The required functions of the EPA as stipulated in Section 2 of the Act, includes inter alia, to:

Prescribe standards and guidelines relating to pollution and discharge of toxic wastes and control of toxic substances ; co-ordinate the activities of relevant bodies and control the generation, treatment, storage, transportation and disposal of industrial waste; control the volume, types, constituents and effects of waste discharges, emissions, deposits or any other source of pollutants and/or substances which are hazardous or potentially dangerous to the quality of the environment or a segment of the environment; and control and prevent the discharge of waste into the environment and protect and improve the quality of the environment. Though no specific reference is made to e-waste in this act, it provides a framework for the management of hazardous substances - a category which e-waste falls under.

Environmental Assessment Regulations, 1999 (LI 1652)

The Environmental Assessment Regulations was adopted on 18th February, 1999. It provides the procedures to be followed before the commencement of activities or projects with the potential of causing serious harm to the environment or human health. The regulation mandates all persons not to commence activities of any undertakings that has or is likely to have adverse effect on the environment or public health, unless an environmental permit has been issued by the EPA in respect of the undertaking. E-waste recycling activities has the potential of causing serious harm to environment and human health and therefore an environmental impact assessment (EIA) is required before the commencement of such an activity. The EPA has the authority to require an EIA for e-waste processing activities and is responsible for ensuring compliance with EIA procedures.

Management of Ozone Depleting Substances and Products Regulations, 2005 (L.I. 1812)

This regulation came into force on 30th June 2005, after Ghana ratified the 1987 Montreal Protocol to bring domestic laws in conformity with the convention. Through the use of licensing mechanism, the regulation restricts the import or export or use of controlled Ozone Depleting Substances or products (including refrigerators and freezers containing Chlorofluorocarbons (CFCs) as refrigerant).

Customs, Excise and Preventive Service (Management) Law 1993 (PNDCL 330)

This law regulates all imports and exports of goods into and out of Ghana. The law does not have any specific regulations on e-wastes but the general objectives and functions of CEPS ensure the monitoring of the importation and exportation of goods, including hazardous chemicals, and (used) electrical and electronic equipment and for that matter e-waste into the country. The law also gives power to custom officers to search persons, premises and baggage and seize prohibited goods, which currently includes used refrigerators, refrigerator-freezers, freezer and used air conditioners.

Export and Import Act, 1995 (Act 503)

The Export and Import Act (Act 503 of 1995) controls imports and exports of all goods (including electrical and electronic equipment) into and from the country. According to this Act, all commercial imported goods (including electrical and electronic products) shall be subject to destination inspection at the port or point of clearance in the country so as to ensure that the quality, quantity, price and other specifications of the imported goods are in conformity with the particulars on the relevant import documents. Used EEE imports have to pass through customs procedures for proper examination, appraisal, assessment and evaluation as part of the clearance procedure.

Energy Efficiency Regulations, 2008

This Regulation bans the importation, sale or distribution of used refrigerators, refrigerator-freezers, freezer and used air conditioners. It also prohibits the manufacture, importation, storage or distribution of incandescent filament lamps in Ghana. However, the regulation does not apply to certain types of incandescent filament lamps which are motor vehicle lamps, flood lights, street lights, halogen lights, spotlights or searchlights, airport runway lights and special purpose lights including theatre or stage lights. Though important, implementation / enforcement of this regulation, particularly the ban on the importation, sale or distribution of used refrigerators, refrigerator-freezers, freezer and used air conditioners is likely to have potential adverse socio-economic impacts on the businesses of importers, retailers as well as consumers of these UEEE products.

Draft Bill on Hazardous and Electronic Waste Control and Management, 2011

The 2011 draft bill on Hazardous and Electronic Waste Control and Management, provides for the control, management and disposal of hazardous waste and electronic waste and for related purposes. It foresees prohibition of the importation, exportation transportation, sell, purchase or any dealing in hazardous waste such as e-waste in the country, but also stipulates certain criteria that must be met before the importation or exportation of such waste can be permitted into/ out of the country. The disposal of hazardous waste on any land in the country or in the territorial waters, contiguous zone, and exclusive economic zone or in a lagoon or the inland waters of the country will be banned by the Bill.

The provisions of the Bill further provide for the establishment of an electric waste recycling plant to be managed the EPA, and mandates Municipal and Metropolitan Assemblies to designate assembly points for the disposal of e-waste. It will also permit the setting up of e-waste processing plants by private individuals who are able to meet certain stipulated requirements and obtain approval from the EPA. To increase recycling and environmentally sound disposal of e-waste, the bill provides for the creation of a collection and take back schemes and obligates consumers to return such wastes to the retailer, manufacturer or importer of the equipment or to a disposal facility designated by the District, Municipal or Metropolitan Assembly.

The bill currently has no legal status and also contains some definition problems among other loopholes and likely to face implementation challenges if not addressed. For instance, the interpretation of illegal traffic in Article 27 to mean " any transboundary movement of hazardous wastes or other wastes" is incomplete. Furthermore, though the informal sector plays a crucial role in the collection of e-waste in Ghana, the bill fails to make provision for informal collection schemes.

2.5.2. International Legislations

Ghana is a signatory to a number of international treaties or conventions with relevance to e-waste imports / management. Key among them are the:

1. Basel Convention;
2. Montreal Protocol on Substances that Deplete the Ozone Layer;
3. Stockholm Convention on Persistent Organic Pollutants; and
4. Bamako Convention

The Basel Convention

The Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and their Disposal regulates the transboundary movement of hazardous wastes and other wastes. The Basel Convention was adopted on 22 March 1989, and came into force on 5th May 1992 for the purpose of, inter alia, reducing hazardous waste generation and promoting their environmentally sound management, wherever the place of disposal, and prohibiting the shipments of hazardous wastes to countries without capacity to manage them in an environmentally sound manner (http://www.basel.int/text/documents.html)

The Convention does not totally ban international trade in wastes, but rather, regulates the transboundary movements of wastes by applying the "Prior Informed Consent" procedure. It prohibits waste exports to nations that have banned such imports, considers illegal waste traffic a criminal offense, and requires each Party to Convention to introduce appropriate national/domestic legislation to prevent and punish illegal traffic (Osibanjo, 2010a). The convention also enjoins parties to ensure that export / import of waste is carried out only where the State of export is without technical facilities and capacity to dispose of the waste in an environmentally sound and efficient manner or where the waste in question is raw material for recycling or recovery industries in the State of import.

Clapp (2002) has argued that though there was a significant reduction in the exports of toxic waste for disposal in developing countries after the entry into force of the Convention, the waste trade began to assume a new form under the guise of recycling due to a loophole in the rules (Vasudev, 2005). While recycling offered the possibility of providing raw materials for manufacturing, the processes employed in developing nations have only resulted in detrimental environmental outcomes. A large proportion of toxic wastes destined for recycling operations in the developing world were in fact, not recyclable. Hence, these activities began producing effects similar to disposal (Vasudev, 2005).

In an effort to close the recycling loophole, an amendment to the Basel Convention (Ban Amendment) was adopted in 1995, to strengthen the convention by prohibiting all transboundary movements of hazardous wastes from Organisation of Economic Cooperation and Development (OCED) member States to non-OECD States(i.e. from developed/wealthy nations to developing /economies in transition countries) for final disposal operations.

However, according to Clapp (2002) (Vasudev, 2005), even with the Amendment, there remain weaknesses that allow the exports to continue. For example, the Amendment does not ban toxic waste trade among the developing or developed countries. Moreover, besides the regulations governing e-waste trade, the Amendment does not address the issue of waste-generating industries from developed countries relocating to developing countries that have relatively less strict environmental regulations and releasing large quantities of pre-consumptive toxics (Vasudev, 2005).

Ghana became a Party to the Convention on 30th May, 2003, but the Convention is currently not in force in Ghana because the country is yet to fully domesticate the provisions of the Convention into its national laws. Although Convention does not define e-waste, List A of Annex VIII of the Convention, classifies the components of e-waste (such as accumulators and other batteries containing lead and cadmium, mercury-switches, glass from cathode-ray tubes and other activated glass, and Polychlorinated Biphenyl (PCB)-capacitors) as hazardous to environment and human health, and, hence, regulates its trans-boundary movement among member states.

The relevance of the Convention to this study stems from the fact that though Ghana is yet to domesticate the Convention into national laws, the majority of UEEE flow and by implication e-waste flow to Ghana are from developed countries particular in the EU that have domesticated the provisions of the convention into regional/national laws and hence obliged to ensure that hazardous wastes such as e-waste are not transported from their countries to a developing country like Ghana , for final disposal operations.

Montreal Protocol on Substances that Deplete the Ozone Layer

The 1987 Montreal Protocol is an international agreement that seeks to protect the ozone layer by a systematic and controlled phasing out of the production and consumption of ozone depleting substances (ODS) such as Chlorofluorocarbons (CFCs). Main categories ODS include Chlorofluorocarbons (CFCs) which were once used in almost all refrigeration and air-conditioning systems. The Protocol was signed on 16 September 1987 and came into force on 1 January 1989. Ghana ratified the Montreal Protocol and its London Amendment on July 24, 1989 and July 22, 1992, respectively.

This protocol is relevant to this study because some UEEE imports arriving at Ghana's ports include prohibited used refrigeration systems with CFC refrigerants. Furthermore, the current e-waste management practices such as the open burning of insulating foam, primarily polyurethane (PUR), from obsolete refrigerators, as co-fuels to sustain the fires used for burning cooling grills of air conditioners leads to the release of ozone depleting CFCs in the atmosphere.

The Stockholm Convention on Persistent Organic Pollutants

The 2001 Stockholm Convention on Persistent Organic Pollutants is a global treaty to protect human health and the environment from chemicals that remain intact in the environment for long periods, become widely distributed geographically and accumulate in the fatty tissue of humans and wildlife. The Stockholm convention entered into force in 2004. It requires Parties to take measures to eliminate or reduce the release of persistent organic pollutants (POPs) into the environment. POPs are classified into two categories: those that are intentionally produced and those that are not. The intentionally produced POPs include industrial chemicals that may be traded between countries. The unintentionally produced POPs are by-products of industrial or other processes involving combustion (for example, open burning of e-wastes) which are not products in commerce.

The list of chemicals currently controlled under the Stockholm Convention contains 22 POPs including polychlorinated biphenyls (PCBs), polychlorinated dioxins and furans (SBC, 2011) which are of concern in relation to electrical and electronic equipment / e-waste. The Convention does not allow for recovery, recycling, reclamation, direct reuse or alternative uses of POPs, with the exception of the recycling of articles containing listed brominated flame-retardants (SBC, 2011). These substances are contained in for instance plastics, circuit boards, photo resistant and anti-reflective coatings or are unintentionally produced during processes such as the open burning of electronic waste (SBC, 2011). The import/export of POPs included in the Convention is allowed only for the purpose of environmentally sound disposal or permitted under the convention for the importing party. All other imports and exports between parties are prohibited. Ghana signed the Convention on 23 May 2001 and ratified it on 30 May 2003.

The Bamako Convention

Dissatisfied that the Basel Convention was not far reaching enough by excluding radioactive wastes, African countries established an African Regional Convention, the Bamako Convention on the Ban on the Import into Africa and the Control of Transboundary Movement and Management of Hazardous Wastes Within Africa in 1991 (Osibanjo,2010b). The Bamako Convention came into force on 2nd April 1998. Ghana is one of the counties that have ratified the Convention but yet to domesticate it into its national laws.

The regional Convention bans all imports of hazardous wastes (which includes e-waste), irrespective of any reason, from non-Contracting parties into Africa. Such imports are deemed illegal and a criminal act. All Parties to the convention are required to take appropriate legal, administrative and other measures within the area under their jurisdiction to prohibit the import of all hazardous wastes including e-waste. The convention also enjoins parties to minimise the production of hazardous wastes and co - operate to ensure that hazardous wastes such as e-wastes are treated and disposed of in an environmentally sound manner.

The European Regulation

The relevance of the European legislation to this study is that the bulk of UEEE imports and by implication e-waste originates from Europe which unlike the US, has laws on e-waste which affects not only the EU member states, but also their trade partners such as Ghana. Key EU regulations on e-waste management are the Waste Electrical and Electronic Equipment (WEEE) Directive, and the Waste Shipments Regulation (WSR -Council Regulation (EC) 1013/2006).

The WEEE Directive of the European Parliament and of the Council (2002/96/EC) was adopted in 2003 with the aim of preventing the generation of waste electrical and electronic equipment, and promoting reuse, recycling and other forms of recovery of such wastes so as to reduce the disposal of waste. Despite the extensive legislation in addressing the WEEE problem, the occurrence of loopholes and difficulties in enforcement have reduced the effectiveness of the EU legislation. It has been found that, of the vast majority of WEEE, 67 percent is completely unaccounted for, being either landfilled or destined for illegal export to developing countries (ComputerAid International, 2010, in Lundgren, 2012).

As a response to these unsatisfactory outcomes, the European Commission commenced revising the Directives in 2008 with the aim of increasing the amount of e-waste that is appropriately treated and reducing the volume that goes to disposal, and also, to better control the illegal trade of e-waste (Lundgren, 2012). On 7 June 2012, the EC adopted a directive that both increases the amount of e-waste which must be collected annually by member states and establishes producer responsibility (Lundgren, 2012).

The Waste Shipments Regulation of the European Union, seeks to implement the provisions of the Basel Convention and the OECD regulation by ensuring that the disposal of waste is done in an environmentally sound manner (Ayodeji, 2011). According to the provisions of the Waste Shipment Regulation (WSR), the transboundary shipment of waste with hazardous characteristics from Europe to any non OECD-member (which includes Ghana) is illegal. Even those items that are classified as non-hazardous waste are not allowed to be exported into the vast majority of non-OECD countries for disposal. However, the WSR takes the import policy of the country of import into account (SBC, 2011). Currently Ghana does not have any national law prohibiting the importation of non-hazardous e-waste from the EU. Therefore the regulation requires that for the export of non-hazardous e-waste from the EU states to Ghana a notification procedure should be to be followed.

2.6. Theoretical Framework: The Pollution Haven Hypothesis

The pollution haven hypothesis (PHH) is a fundamental concept in the trade and the environment literature (Mathys, 2003), and can be traced back to Walter's (1978) investigation of environmental attitudes in less developed countries (Lepawsky and McNabb, 2010). The hypothesis posits that pollution-intensive economic activity will tend to migrate to those jurisdictions where costs related to environmental regulation are lowest. Other versions of the hypothesis also propose that in the pursuit of capital investment, jurisdictions will compete with one another to drive down investment costs, including those related to pollution control, thus leading to poorer jurisdictions most desperate for investment being disproportionately affected by polluting industries (Lepawsky and McNabb, 2010). In other words, the poorer nations end up becoming "pollution havens".

According to Neumayer (2001), the most important factor that could lead to pollution havens is that developing countries might suffer from political institutional deficiencies that could create a bias against environmental preferences such that their environmental standards are set inefficiently low or are not enforced. Furthermore, whereas the benefits of pollution are present, tangible, and highly visible in terms of the goods and services that are produced and the jobs that are created or secured, the costs of pollution are often invisible, intangible, uncertain, and occur in the future.

The validity of the pollution haven hypothesis (PHH) continues to be one of the most controversial issues in the debate regarding international trade and the environment (Kellenberg, 2008). For example, Leonard (1988), in one of the earliest comprehensive qualitative studies, did not find evidence of pollution-intensive U.S. industries moving to Ireland, Spain, Mexico, or Romania (Neumayer, 2001). Similarly, Birdsall and Wheeler (1993), drawing on case studies and econometric evidence, argue that increased foreign investment in Latin America has not resulted in an increase in pollution-intensive industrialization (Lepawsky and McNabb, 2010).

Wagner and Timmins (2008) on the other hand find strong support for the pollution haven hypothesis in their study of foreign investment decisions of the German chemical industry. Furthermore, Cave and Blompist (2008) in their study of the EU found that the pollution haven hypothesis holds for energy-intensive trade, but not for toxic intensive trade (Lepawsky and McNabb, 2010). Bernard (2010) has explored the driving forces for the movement of illegal waste, paying particular attention to the role of local waste regulations, such as the EU's Waste Electrical and Electronic Equipment directive, and finds that increased regulation stringency in the North leads its firm to reduce the degree of reusability of its products. As a result, the flow of non-reusable waste to the South increases, providing another channel for the Pollution Haven Hypothesis.

Lepawsky and McNabb (2010) also tested the utility of the pollution haven hypothesis for explaining the observed trade patterns in the global trade of e-waste. Their results showed a systematic relationship between net e-waste trade balance and Gross Domestic Product (GDP) per capita of trading countries that supports the pollution haven hypothesis. They found that as GDP per capita declines, the likelihood that a given country is a net importer of e-waste increases. However, they argued that the pollution haven hypothesis may be both empirically and conceptually limiting in terms of understanding the realities of the trade and traffic of electronic waste and their broader theoretical implications for how they understood the geographies of waste and value.

According to Clapp (2002), the lack of consensus in the literature on pollution havens may arise from three important limitations to how the pollution haven debate tends to be framed (Lepawsky and McNabb, 2010). The first limitation is the bias towards the manufacturing industries as an indicator of the presence of pollution havens; such definitions leave out, for example, waste processing and disposal industries as indicators of pollution havens. Secondly, the definition of dirty industries tends to mask 'degrees of dirtiness' (in other words, manufacturing asbestos, benzedine-based dies or pesticides is not the same as manufacturing textiles or steel). Thirdly, pollution haven studies tend to focus on direct pollution abatement costs, leaving other important environmental costs uncounted such as 'protest factor' costs, which include costs related to public relations on environmental issues, liability costs, insurance costs and certification costs (e.g., ISO 14000), all of which are very difficult to measure across whole industrial sectors.

This study adopted the version of the PHH that proposes that in the pursuit of capital investment, jurisdictions will compete with one another to drive down investment costs, including those related to pollution control, thus leading to poorer jurisdictions most desperate for investment being disproportionately affected by polluting industries (Lepawsky and McNabb, 2010). This study further examined the utility of the PHH in explaining the flow of used computer imports and by implication e-waste flow to Ghana. This was done by using available data on used computers imports as captured by Ghana Customs. Attempts were made to relate the volume of import flow of such imports to Ghana with the GDP of the countries of export. The PHH was found to be true if the countries of export are of higher GDP (richer) than that of Ghana and vice versa.

2.7. Summary

This chapter highlighted findings from the literature review conducted as part of the research work. Specifically, it answered the question of what is e-waste and discussed the why e-waste is considered as both beneficial and hazardous waste. It emphasized on certain hazardous heavy metals constituents of e-waste and discussed their uses in EEE, exposure routes and potential adverse environmental and health impacts. The existing e-waste situation in Ghana was also discussed in this chapter. It was noted that a significant proportion of UEEE imports are old, near or at end-of-life and are sooner or later discarded as e-waste, thus leading higher e-waste generation per year. The management of e-waste in Ghana is dominated by the workers the informal sector who derive livelihood benefits from the management of e-waste. The sector is also faced with environmental and health challenges as result of their crude management practices. There are number of national and international regulations related to the management of e-waste. Some of them contain some loopholes and others are yet to be implemented in the country. The importance and limitations surrounding the utility of the pollution haven hypothesis was finally discussed in this chapter. The appropriate methodologies used to investigate the key research questions and achieve the objectives outline in this study are discussed in the next chapter.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Introduction

This chapter outlines the methodology used in collecting, analysing, and presenting the data for this research. It first begins with a brief description of the study area, highlights on the ethical considerations and then describes the sampling procedures and the methods used in the collection and analysis of data for this study. The methodology is necessary to ensure that the research project comprehensively addresses the research questions (Cresswell, 2003 in Goh, 2011).

3.2 Study Area: Accra- Tema Metropolitan Area

Ghana, like other developing nations of West Africa, has become one major destination for e-waste worldwide (Asante *et al*. 2012). The selection of the Accra-Tema Metropolis which happens to be a coastal area located in the Greater Accra Region of Ghana as an area for case study is because Accra serves as the national capital of Ghana, and also the largest city in terms of industrial establishment and infrastructural development. More than 70 percent of Ghana's manufacturing capacity is located in Accra (Asante *et al*. 2012). Also located in Accra is Agbogbobloshie the hub of informal e-waste recycling in Ghana (Brigden *et al.*, 2008; Oteng-Ababio, 2011).

The Tema Metropolitan Area on the other hand was chosen because it has the largest seaport in Ghana. Specifically, four study sites were chosen within the Accra-Tema Metropolitan Area, namely, Tema Port, Tema Community One Market, Ashaiman and Agbogbloshie e-waste recycling sites.

3.2.1 Tema Port

Opened to regular marine traffic in 1962, the Tema Port is the bigger of two seaports in Ghana. It is located in the south-eastern part of the country (along the Gulf of Guinea), about 29 kilometres from Ghana's capital city, Accra. The port (shown in Figure 3.1) covers a land area of 3.9 million squares metres (http://www.ghanaports.gov.gh), and is flanked by an industrial city. The port receives an average of over 1650 vessel calls per year and these comprise an assortment of container vessels, general cargo vessels, tankers, Ro-Ro and cruise vessels amongst many others (www.ghanaports.gov.gh).

The ports environs serve as a logistic point for activities of Inland Clearance Depots (ICDs), Warehouses, Transport and haulage companies, freight forwarders and related service centres. Majority of the national trade and traffic is done through Tema port with additional volumes of trade and traffic to and from the landlocked countries of Burkina Faso, Mali and Niger. The port is the main entry point of importation of electrical and electronic products and other goods to Accra and other parts of Ghana. The Port of Tema thrives on the multiplicity of businesses that grow the Ghanaian economy and that of regional neighbours.

The Tema Port is being managed and operated by the Ghana Ports and Harbours Authority (GPHA). Most marine services including pilotage, towage and mooring are provided by the Port authority. Stevedoring services are provided by private companies in addition to the port’s stevedoring section in order to increase competition, encourage efficiency, and improve service delivery and increase customer service and satisfaction (http://www.ghanaports.gov.gh).

Figure 3.1: Map showing Tema Port.

Source: http://www.ghanaports.gov.gh.

3.2.2. Tema Community One Market

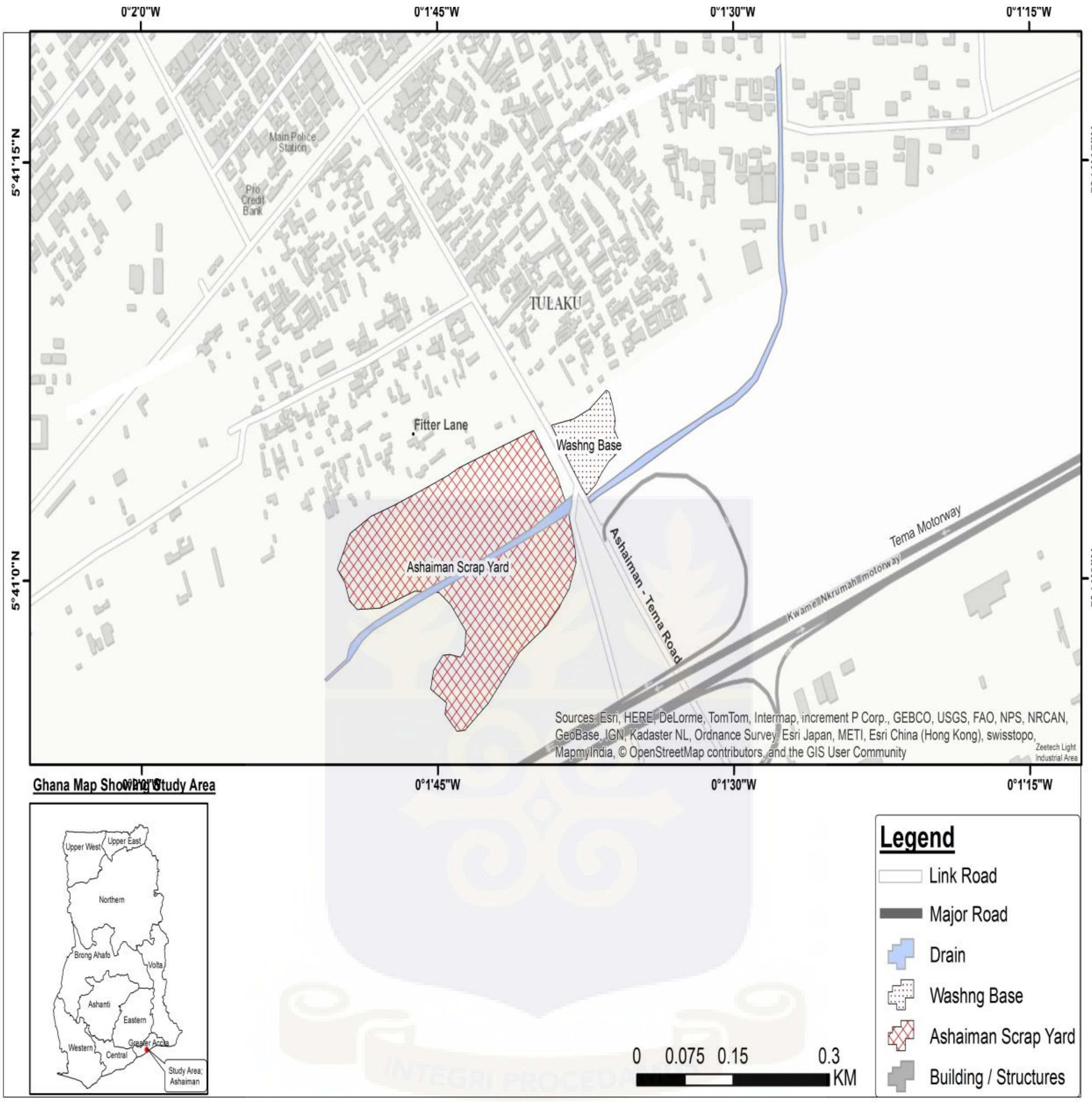
Tema Community One is the Central Business District of the Tema metropolis. The residents are petty traders, artisans, tradesmen and professionals. The e-waste (dismantling) site (shown in Figure 3.2) at the Tema Community One Market can be found along the Nana Kena street, near the Presby Church (which lies on latitude 05^{o}38'34.43"N and longitude 0^{o}0'1.95"E). Currently, the e-waste site occupies a land size of about 140.60 m^2. The main e-waste recycling activity currently being carried out at this site which happens to be by the road side is dismantling. It was observed during the field visit that, unlike other e-waste sites like the Agbogbloshie and Ashaiman e-waste sites, open burning is presently not a normal feature at the this e-waste site. According to the e-waste workers at this site, they fear being

3.2.3 Ashaiman Washing Base Scrap Yard / E-waste Site

Ashaiman is located about 4 kilometres to the north of Tema and about 30 kilometres from Accra, the capital city of Ghana, and shares boundaries on the north and east with the Katamanso Zonal Council of the Tema Metropolitan Assembly (TMA), on the south with the Tema Town Centre, and on the west with Adjei Kodjo, a community which forms part of the Tema Zonal Council.

The Scrap yard / e-waste site is located at a place called Washing Base (located on latitude 05^{o}41’4.99”N and longitude 00^{o}01’37.28”W) which is close to the Ashaiman 'Fitalane' and along the Ashaiman-Tema road. Observed during the field visit was a large dumpsite near the scrap yard, with all kinds of domestic solid wastes including waste papers and plastics scattered all over. According to the current chairman of the Washing Base Scrap Dealers Association, the scrap yard has been in existence for over 15 years now, and is one of the major scrap centres for all kinds of scraps including disused fridges, televisions, computers and car parts in Ashaiman. E-waste recycling activities in this area include dismantling and open burning.

Figure 3.3: Map showing Scrap Yard at Ashaiman.



Source: Author's Fieldwork (2013).

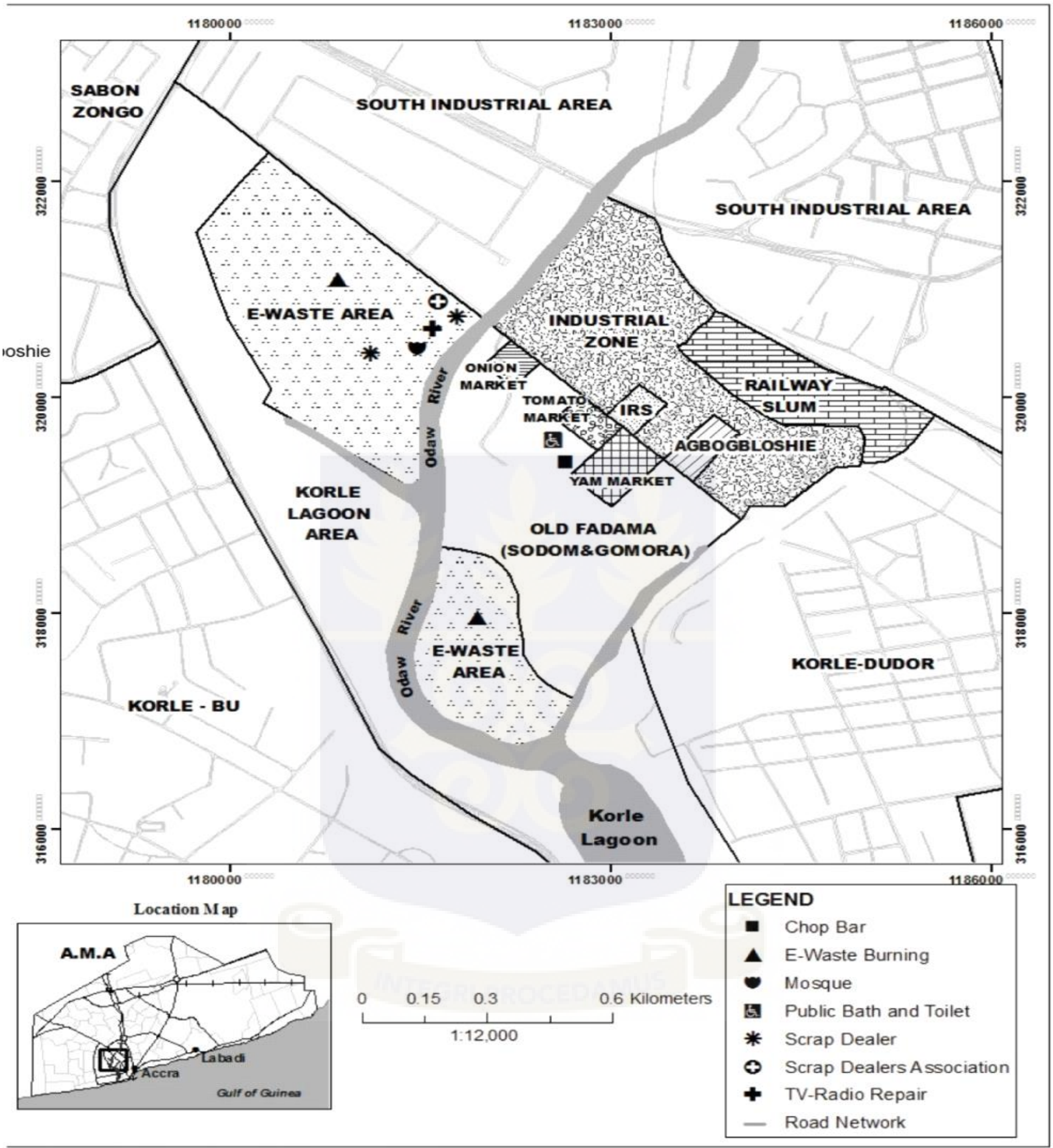
3.2.4. Agbogbloshie Scrap Market

The Agbogbloshie Scrap Market (shown in Figure 3.4) is located in Accra, the largest city in Ghana in terms of establishment and infrastructural development. The Agbogbloshie Market is situated on the left bank of the Odaw River, and in the upper reaches of the Korle Lagoon. The area is on flat ground, and during periods of heavy rain-fall much of the site becomes flooded (Brigden *et al.*, 2008). Presently, the Agbogbloshie area is about 31.3 hectares and less than a kilometre from the Central Business District (CBD), with an estimated population of 79,684 ("Housing the Masses", 2010: 2; Oteng-Ababio, 2011). It is engulfed by urban commercial development due to the rapid spatial expansion of Accra (Oteng-Ababio, 2011).

Agbogbloshie is known to be the main centre for e-waste recovery in Ghana (Brigden *et al.*, 2008). The Agbogbloshie site started as a food stuff market for onions and yam. Over the years the area has grown into a slum with people dealing in all sorts of scrap on a large scale. The scrap dealers discovering the place as a good location for business later registered with the National Youth Council as the Scrap Dealers' Association of Ghana, and the land was leased to them in 1994 (Amoyaw-Osei *et al*., 2011; (Asante *et al*., 2012).

The scrap yard has grown steadily into a popular recycling area and is reputed to be the dumping ground (Asante *et al*., 2012) for disused computers, TVs, and other electronic and electrical devices as well as household waste (Asante *et al*., 2012). Recycling activities carried out at the Agbogbogbloshie site include manual dismantling and open burning of e-waste to recover valuable materials.

Figure 3.4: Agbogbloshie e-waste site.



Source: Oteng-Ababio (2012).

3.3. Research Methodology

As the overall objective of this study is to analyse the flow of used electrical and electronic equipment imports into Ghana and how such imports are handled at the port; and further assess the potential environmental and health challenges associated with the current management practices, the combination of quantitative and qualitative field research (mixed-method research) was applied as the appropriate approach. According to Clarke (2009), the combination of quantitative and qualitative approaches is particularly useful when the methods examine different facets of the same problem. Sharan (2002) also argues that there are multiple constructions and interpretations of reality and as such mixed methods offer a tool for understanding complex problems (Teye, 2012). Therefore, for these reasons mentioned above, the combination of quantitative and qualitative research methods was used in undertaking this study.

The specific sampling techniques employed in this study were purposive and random sampling techniques. Data for this study were obtained from both primary and secondary sources. Data were collected by adopting multiple methods of data collection namely interviews, observations and review of documents. Environmental and biological samples were also collected and later analysed in the laboratory. The selection of data gathering methods and data sources were guided by the objectives and research questions. The sampling and data collection methods employed in this study are discussed below in detail. The period of data collection extended from early March 2013 to end of July 2013.

3.4. Ethical Consideration

Ethical clearance was sought from and approved in writing by the Noguchi Memorial Institute for Medical Research Institutional Review Board (NMIMR-IRB) (Appendix A1) prior to the collection of the biological (urine) samples from potential subjects. Since some of the subjects (particularly, the e-waste workers and control group) in this study were children, assent and parental consent forms were respectively used to seek the permission of the children and their parents.

Furthermore, prior to the port visit for the purposes of observing UEEE handling operations and interviewing relevant stakeholders in the port, a written approval was obtained from the Ghana Ports and Harbours Authority (GPHA) (Appendix, A2) and the Customs Division of the Internal Revenue Service at the Tema Port (Appendix, A3). An informed consent was also sought directly by meeting with the subjects/respondents to willingly volunteer to be part of the study. It entailed the purpose of the study, benefits and privacy/ confidentiality. Participation was absolutely voluntary and each subject/respondent had the opportunity to participate or opt out at any point in the course of the survey. A tin of milo was provided as an incentive to each subject involved in the urine sampling.

3.5. Sampling and Data Collection Methods

Purposive random sampling technique was used in the selection of regulatory officials / authorities (Customs Division of the Ghana Revenue Authority, Ghana Standards Authority (GSA), GPHA, and EPA) involved in the handling of UEEE imports, based on their key role in the handling of UEEE imports in the port. Same sampling technique was used in the selection of respondents involved in the importation (clearing agents and importers) and sale (retailers) of UEEE.

The main consideration in purposive sampling, according to Kumar (2005:179), is the judgement of the researcher as to who can provide the best information to achieve the objectives of the study. He posits that the researcher only goes to those people who in his/her opinion are likely to have the required information and be willing to share it and thus supports this type of sampling as extremely useful when a researcher wants to construct a historical reality, describe a phenomenon or discover something about which only a little is known. The goal of using this method as Creswell (2003) maintained, is to focus on obtaining an in-depth knowledge of a phenomenon (Tackie, 2012). Random sampling technique was employed in the selection of respondents/subjects (e-waste workers and control group) who participated in the biological (urine) sampling, based on their willingness to participate in this study.

One of the data gathering techniques used in this study was interview. A sample of interview questions can be found in Appendices: F1 to F3. Table 3.1 shows that a total of 60 respondents were involved in this study. In-depth interview was conducted with a total of sixteen regulatory officials (shown in Table: 3.1) involved in the handling of UEEE imports in the port. Interviews were also conducted with five clearing agents, four importers and three retailers of used electrical and electronic equipment (Table: 3.1). The interview questions for these respondents primarily focused on UEEE handling operations, challenges and the way forward. The interview questions were open-ended so as to minimize the use of leading questions.

Interviews were also conducted with a total of twenty four e-waste workers, comprising eight participants each from Agbogbloshie, Ashaiman and Tema e-waste sites (Table: 3.1) Furthermore, interviews were conducted with eight participants from Mataheko who served as a control group (not engaged in e-waste work activities). The interviews with the e-waste and control group participants were done using semi-structured questionnaires which takes on a middle position between the structured and unstructured types of interviewing. Notably, the e-waste workers and the control group participants who were interviewed in this study, were the same subjects who volunteered to participate in the biological (urine) sampling, hence the relevance of the interview questions. The interview questions for these participants sought to gather information on their age, education, alcohol drinking and smoking habits, region of hometown, current place of residence, and e-waste working years/ handling practices.

Table 3.1: Distribution of respondents

Category of respondents / Agency	Number of respondents interviewed
Regulatory Stakeholders	
Customs Division of the Ghana Revenue Authority	10
GSA	2
GPHA	2
EPA	2
Private UEEE imports Stakeholders	
Importers	4
Clearing Agents	5
Retailers	3
E-waste workers	
Agbogbloshie e-waste workers	8
Ashaiman E-waste workers	8
Tema E-waste workers	8
Control group	8
Total	***60***

Source: Author's Fieldwork (2013).

Observation was another data gathering technique applied in this study for the purposes of checking the validity of data from interviews and gaining sensitive information which might have been concealed by the respondents; as well as getting first-hand information and more understanding on what is really happening on the ground with regard to e-waste management, since there are limitations on how much can be learned from what people say in an interview (Tengku-Hamza, 2011). Observation, unlike the interview method where the data obtained is mainly based on the perception of interviewees, produces data based on the observer's insights and perceptual sense, thus making the observer (researcher), the main 'tool' in this technique (Tengku-Hamza, 2011).

In this study, observation on handling (by regulatory officials), types and physical condition of imported second hand electrical and electronic items was made during a four-day visit to four container terminals (one day visit to each terminal) within the Tema Port, namely, Golden Jubilee Terminal, Shed 10 (managed by the state); African Coastal Services (ACS) and Tema Container Terminal (TCT) (privately managed). Observations on the types of second hand electronic items on sale were also made during a day's visit to the second hand electronics market at Tema Community One. The visits to the port and the second hand electronic market were made in the month of May 2013. Observations were also made during the frequent visits to the e-waste recycling sites under this study. The field data was supported with information from several relevant secondary sources including research journals, policy statements and legislation, manuals, reports, and other scholarly sites on the internet. Information from records of agencies including the Ghana Customs, Excise and Preventive Services (now known as Customs Division of the Ghana Revenue Authority) was also used.

Gathering accurate data on global flows of e-waste is challenging (Grant and Oteng-Ababio, 2012). Similar to many countries in West Africa, Ghana's land frontiers are porous, particularly along certain stretches of its three land borders (i.e., Côte d'Ivoire, Togo, and Burkina Faso), making shipments through unmonitored routes possible (Grant and Oteng-Ababio, 2012). Furthermore, the West African Coastal Highway serves as a major transportation route for trucks to transport goods within the region. Currently, data captured at border crossings are not yet coordinated by the Economic Community of West African States (ECOWAS) (Grant and Oteng-Ababio, 2012).

For these reasons, since computers account for relatively the largest share of e-waste in Ghana and are also less likely to be smuggled because of their duty free status (Grant and

Oteng-Ababio, 2012), the origins / flow of UEEE imports were analysed using data on used computer imports as recorded by the Ghana Customs, Excise and Preventive Services (CEPS) data management system (GCNet/GCMS). The Ghana Customs, Excise and Preventive Services (CEPS) data management system (GCNet/GCMS) compiles and aggregates trade data from almost all official entry points (Grant and Oteng-Ababio, 2012). Although some (minor) official entry points (e.g., Kpoglo near Aflao on the Ghana–Togo border; Kulumgugu next to Paga on the Ghana–Burkina Faso border, and Osei Kojo Kurom on the Ghana–Côte d'Ivoire crossing) are not networked into GCNet/GCMS, mainly because these posts lack electricity, these data are reasonably comprehensive, capturing information on country of origin, importer (consignee), description (type) of commodity, net mass and cost, insurance, and freight (CIF) value as well as duty paid (Grant and Oteng Ababio, 2012).

3.5.1. Soil and Urine sampling

To assess the level of environmental and human exposure to hazardous chemicals associated with the current e-waste management practices at the selected e-waste recycling sites, environmental (soil) and biological (urine) samples were collected and analysed at the laboratory.

3.5.1.1. Soil Sampling

Soil sampling was conducted within the month of March 2013. Based on the type of e-waste processing activities being carried out at the respective e-waste sites, the Agbogbloshie and Ashaiman e-waste sites were each divided into three sampling stations, namely, dismantling station (STA), open burning station (STB) and disposal station (STC). Since the current e-waste activity being conducted at the Tema Community One Market e-waste site is dismantling, the entire e-waste site was designated as a dismantling station (STA).

Thereafter, at each designated sampling station, surface soil samples were randomly collected from three sampling points at depths, 0-5; 5-10 and 10-15 cm, using depth calibrated soil auger. These depths fall within the range of soil depths of much greater exposure to humans. Thus, 12 soil samples were obtained from each designated sampling station at each e-waste site in this study. This implies that thirty six (36) soil samples each were collected from both Agbogbloshie and Ashaiman e-waste sites, while 12 soil samples were collected from the Tema Community One Market e-waste (dismantling) site. To serve as control, twelve (12) surface soil samples were randomly collected at same depth range from a non-e-waste processing area at Mataheko, which is about 3 km away from Agbogbloshie in Accra. Altogether, 96 soil samples were collected for this study.

The locations (Appendix B) of the sampling points were determined using a handheld GPS with the coordinates recorded at an accuracy level of 3 meters. The samples were individually placed into clean labelled zip-lock polythene bags and were then transported to the Ghana Atomic Energy Commission (GAEC) laboratory in Accra (Appendix: C) for digestion and heavy metals (Pb Cu, Sb, Zn, As, Cd and Hg) analyses.

3.5.1.2. Urine Sampling

Urine sampling was conducted in the month of July, 2013 between the hours of 9.00 and 10.00 GMT. After an informed consent had been obtained from all donors in an ethical manner, spot urine samples were randomly obtained from a total of 32 participants, comprising 24 e-waste workers (e-waste working group) and eight (8) subjects who served as a control group (were not engaged in any e-waste processing activity). The e-waste participants consisted of 8 workers each from Agbogbloshie, Ashaiman and Tema e-waste sites. The subjects who served as control all live at Mataheko, about 3 km from Agbogbloshie in Accra. As indicated earlier, information on the subjects` age, sex, education, alcohol drinking and smoking habits, region of hometown, current place of residence, and e-waste working years/handling were obtained using semi-structured questionnaire (interview).

All the urine samples were collected into pre-cleaned polypropylene bottles and were stored in an icebox at 4 ^{o}C on the field. The urine samples were then transported to the GAEC laboratory (Appendix C) in Accra on the same day of sampling, where they were immediately kept in a refrigerator until digestion and heavy metals (Pb, Cu, Sb, Zn, As, Cd and Hg) analyses. Concentrations of the heavy metals in the urine samples were determined using VARIAN AA 240FS- Atomic Absorption Spectrometer (AAS).

3.6. Laboratory Analysis of Soil and Urine Samples

3.6.1. Soil Sample Preparation

The soil samples were air-dried for three days, disaggregated using mortar and pestle, and sieved through 0.5 mm mesh. Thereafter, 10 g of sieved soil sample (from each sampling point) was composited (mat-rolled / well homogenised) for digestion and analyses. The compositing of the samples was done to determine the average metal concentration in soil collected from each sampling point (i.e. at 0-15 cm depth range).

3.6.2. Digestion of Soil Samples

After this preparation stage, 1.5 g of each composited soil sample was weighed into a previously acid-washed and labelled 100 ml Teflon bombs, and 6 ml of concentrated nitric acid (HNO_3, 65%), 3ml of concentrated hydrochloric acid (HCl, 35%) and 0.25 ml of hydrogen peroxide (H_2O_2, 30%) were then added to each sample in a fume chamber. The same procedure was repeated for the composite samples and the Certified Reference Material IAEA-SOIL-7 (from International Atomic Energy Agency, Vienna, Austria). The Teflon bombs were then loaded on the ETHOS 900 microwave carousel. The vessel caps were secured tightly using a wrench. The complete assembly was microwave irradiated and allowed to digest for 26 minutes using milestone microwave Labstation ETHOS 900, INSTR: MLS-1200 MEGA. The microwave programme is shown below in Table 3.2.

Table 3.2: Microwave Digestion Report Code 308 programme for soil samples.

Step	Time	Power	Pressure	Temp °C 1	Temp °C 2
1	00:05:00	250	100	400	500
2	00:01:00	0	100	400	500
3	00:10:00	250	100	400	500
4	00:05:00	450	100	400	500
Vent:00:05:00			Rotorctrl on	Twist on	

Source: Milestone Acid Digestion Cookbook update 1st January 1996.

After digestion, the Teflon bombs mounted on the microwave carousel were cooled in a water bath to reduce internal pressure and allow volatilized material to re-stabilize. The digestate was then made up to 20 ml with double distilled water and transferred into test tubes and assayed for the presence of Antimony (Sb), Arsenic (As), Cadmium (Cd) Copper (Cu), Lead (Pb), and Zinc (Zn), using VARIAN AA 240FS- Atomic Absorption Spectrometer (AAS). Mercury (Hg) is highly volatile (Baird and Cann, 2008), therefore the cold vapour technique was used to determine its presence in the samples.

All the metals analysed have known uses in electrical and electronic equipment and therefore globally associated with e-waste, for which they are likely to be released into the environment during e-waste recycling processes such as open burning. The analysis of the metals was expressed in mg/kg. Table 3.3 shows the instrument parameters employed for the determination of the heavy metals.

As part of quality assurance and quality control (QA/QC) measures of the analysis, analytical grade reagents were used (from FLUKA ANALYTICAL, Sigma-Aldrich Chemie GmbH, product of Switzerland). Reagent blanks and duplicates of the samples were digested and analysed at the same conditions as the samples to detect any contamination during the sample preparation, and to check the reproducibility of the method used respectively. Glassware and Teflon bombs were acid washed. Double distilled was used for all the preparations. For the validation of the method (including sample preparation and measurement), certified reference material (from International Atomic Energy Agency, Vienna, Austria) was analysed along with the analytical samples.

Table 3.3: Instrument parameters used for atomic absorption spectrometer analysis

Element	Wavelength (nm)	Lamp Current (mA)	Slit Width (nm)	Fuel	Support
Antimony (Sb)	217.6	10	0.2	Acetylene	Air
Cadmium (Cd)	228.8	4	0.5	Acetylene	Air
Copper (Cu)	324.7	4	0.5	Acetylene	Air
Lead (Pb)	217.0	5	1.0	Acetylene	Air
Zinc (Zn)	213.9	5	1.0	Acetylene	Air
Arsenic (As) (By Hydride)	193.7	10	0.5	Acetylene	Argon
Mercury (Hg) (By Hydride)	253.7	4	0.5	Argon	Air

Source: VARIAN. Publication No 85- 100009-00 Revised March 1989.

3.6.3. Digestion of Urine Samples

Two point five grams (2.5g) of each urine sample collected was weighed into a previously acid-washed labelled 100 ml PTFE Teflon bombs. Thereafter, 5 ml of concentrated nitric acid (HNO_3, 65%) was then added to each sample in a fume chamber. The Teflon bombs (containing the samples) were then loaded onto the ETHOS 900 microwave carousel. The vessel caps were secured tightly using a wrench. The complete assembly was microwave irradiated /allowed to digest for 15 minutes in a Milestone Microwave Labstation ETHOS 900, INSTR: MLS-1200 MEGA. The microwave programme used for the digestion is shown in Table 3.4.

Table 3.4: Microwave digestion Report Code 241 program for urine samples

Step	Time	Power	Pressure	Temp °C 1	Temp °C 2
1	00:05:00	250	100	400	500
2	00:05:00	400	100	400	500
3	00:05:00	600	100	400	500
Vent:00:05:00		Rotorctrl on		Twist on	

Source: Milestone Acid Digestion Cookbook update 1st January 1996.

After digestion, the Teflon bombs mounted on the microwave carousel were cooled in a water bath to reduce internal pressure and allow volatilized material to re-stabilize. The digestate was then made up to 20ml with double distilled water in a volumetric flask and transferred into test tubes and assayed for the presence of Antimony (Sb), Arsenic (As), Cadmium (Cd) Copper (Cu), Lead (Pb), Mercury (Hg), and Zinc (Zn), using VARIAN AA 240FS - Atomic Absorption Spectrometer (AAS). The cold vapour technique was used to determine the presence of mercury in the samples. The analysis of the metals was expressed in mg/l. As part of the QA/QC protocol, reagent blanks and duplicates of the samples and were digested and analysed at the same conditions as the samples to respectively detect any contamination during the sample preparation, and check the reproducibility of the method used.

3.7. Data Analysis

Descriptive frequency analysis was done on the data regarding demographic characteristics, e-waste handling practices, and smoking and alcohol consumption. Trend analysis was also made for the volume of second hand computer imports so as to estimate the likely volume of such imports in future. Soil data obtained from individual sampling stations / e-waste recycling sites in this study were compared among each other, and also compared with that obtained from the control e-waste site.

Similarly, the urine data of the e-waste workers from each e-waste site was compared with that obtained from the control group. Comparison was also made among the e-waste workers with regard to urinary heavy metals concentrations. The data were statistically analyzed using the Statistical Package for Social Sciences, SPSS v. 16.0, Microsoft Excel, and Minitab16.0. A variance analysis of metal concentrations among sampling stations/sites and urine samples was performed using a one-way ANOVA test. Statistical variations were considered significant at $p < 0.05$.

3.8. Summary

This chapter presents the study area of the research and outlines the research methods used in this study. The combination of quantitative and qualitative field research (mixed-method research) was deemed as the appropriate approach. This study employed five distinctive data collection methods namely, interviews, observations, review of documents, environmental and biological sampling. Ethical issues were taken into consideration prior to the interview of respondents and the biological sampling. Generally, purposive and random sampling techniques were employed in this study.

CHAPTER FOUR

FLOW AND MANAGEMENT OF USED ELECTRICAL AND ELECTRONIC IMPORTS TO GHANA

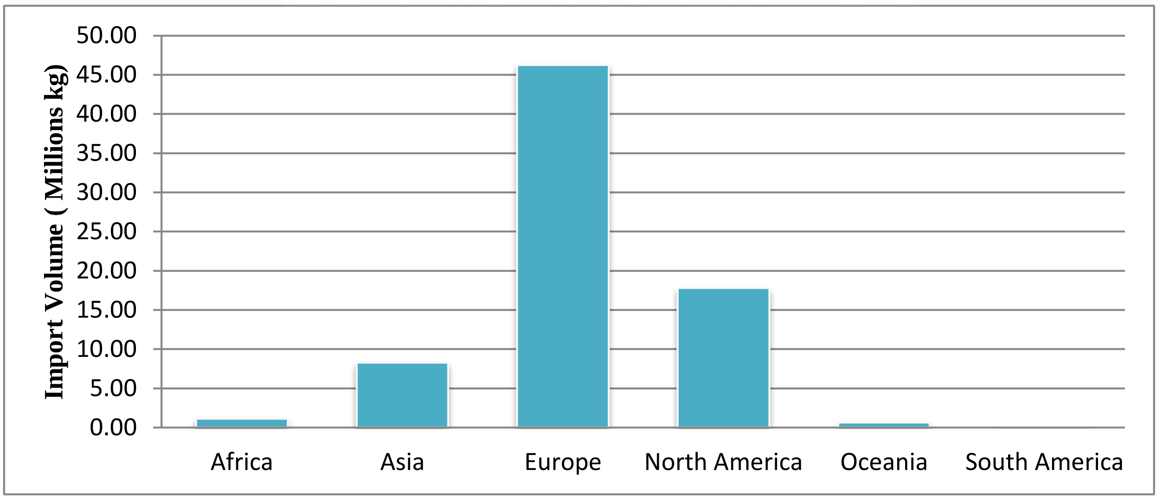
4.1. Introduction

This chapter presents results on the data analysis. It consists of the volume of UEEE imported into the country and how these have been managed. These have been presented and analysed in six parts namely, the origins and volumes of used computer imports, Customs clearance procedures at the Tema Port and its limitations, quality of UEEE imports, the pollution haven hypothesis and e-waste flows to Ghana, e-waste handling activities and socio-demographic characteristics of respondents.

4.2. Origins and Volumes of Used Computer Imports

This study analysed the flow of used computers imports to Ghana between 2004 - 2010 and found that Ghana has become a recipient of large volumes of second hand computer imports from various regions and countries the world over. The sources and volumes of used computer imports to Ghana are shown in Figure 4.1 and Table 4.1.

Figure 4.1: Sources of import flows of used computers to Ghana (2004 - 2010).



Source: Ghana CEPS (2010).

Based on the 2004 to 2010 data, it was observed that the majority of these imports were from the developed regions, particularly Europe followed by North America. Import flow from Asia was observed to be the highest among the developing regions, followed by Africa, Oceania, and then South America (Figure 4.1). This trend was concordant with results of previous study in Ghana by Grant and Oteng-Ababio (2012). Flows from Western Europe and Northern America between the period of 2004 to 2010 were approximately 48% and 24% of the total volume of imports respectively (Table 4.1).

Table 4.1: Volume of Used Computer Imports to Ghana by Sub-region, 2004 – 2010.

Country	Total Volume (kg)	Percentage (%)
Western Europe	35,704,360.97	48.24
Northern America	17,744,293.41	23.97
Southern Europe	8,333,378.50	11.26
Eastern Asia	4,167,110.24	5.63
Western Asia	3,162,517.73	4.27
Northern Europe	2,186,285.13	2.95
South-eastern Asia	730,198.38	0.99
Western Africa	655,377.31	0.89
Oceania	622,408.40	0.84
Southern Africa	363,254.28	0.49
South-central Asia	212,387.02	0.29
Eastern Africa	43,690.35	0.06
Northern Africa	26,970.89	0.04
South America	22,602.49	0.03
Caribbean	16924.41	0.02
Eastern Europe	11,438.17	0.02
Middle Africa	6,397.80	0.01
Central America	4950.42	0.01
Grand Total	**74,014,545.90**	**100**

Source: Ghana CEPS (2010).

The United Kingdom (UK), followed by United States of America were observed to be the leading exporters of used computers to Ghana, and were thus, responsible for about 24.43 percent and 19.59 percent (Appendix D1) of the total volume of imports respectively. Notably, traffic flow from the UK increased consecutively from 2004 to 2008 before registering a decline onwards (Appendix D1). Interestingly, traffic flow for both the UK (4,925,744 kg) and USA (4,336,581 kg) peaked in 2008 and then recorded a decline onwards.

Italy, Germany and France were observed to be the 3rd, 4th and 5th leading exporters of used computers to Ghana respectively (Appendix D1).

Majority of the flows from Eastern Europe and Northern Europe were respectively from the Russia Federation and Denmark (Appendix D1). Similarly, Netherlands Antilles, Australia, Panama and Brazil were observed to be leading exporting countries of used computers from the Caribbean, Oceania and Central America and South America sub regions (Appendix D1) respectively to Ghana. The import traffic from Asia, were mostly from China, followed by the United Arab Emirates, Lebanon and Malaysia in that order (Appendix D1). Also, Guinea followed by South Africa, Nigeria, Senegal and Cote d'Ivoire were the top five countries within the African region exporting second hand computers to Ghana with regard to import quantity. Furthermore, it was observed that most of the imports from northern Africa, middle Africa, and eastern Africa sub regions were respectively from Morocco, Gabon and Mauritius (Appendix D1).

Table 4.2: Volume of Used Computer Imports to Ghana by years, 2004 – 2010.

Year	Total Volume (kg)	Percentage (%)
2004	7,605,085.00	10.28
2005	14,210,356.00	19.2
2006	7,255,473.00	9.8
2007	8,549,190.00	11.55
2008	16,603,317.00	22.43
2009	12,308,625.93	16.63
2010	7,482,498.97	10.11
Grand Total	**74,014,545.90**	**100**

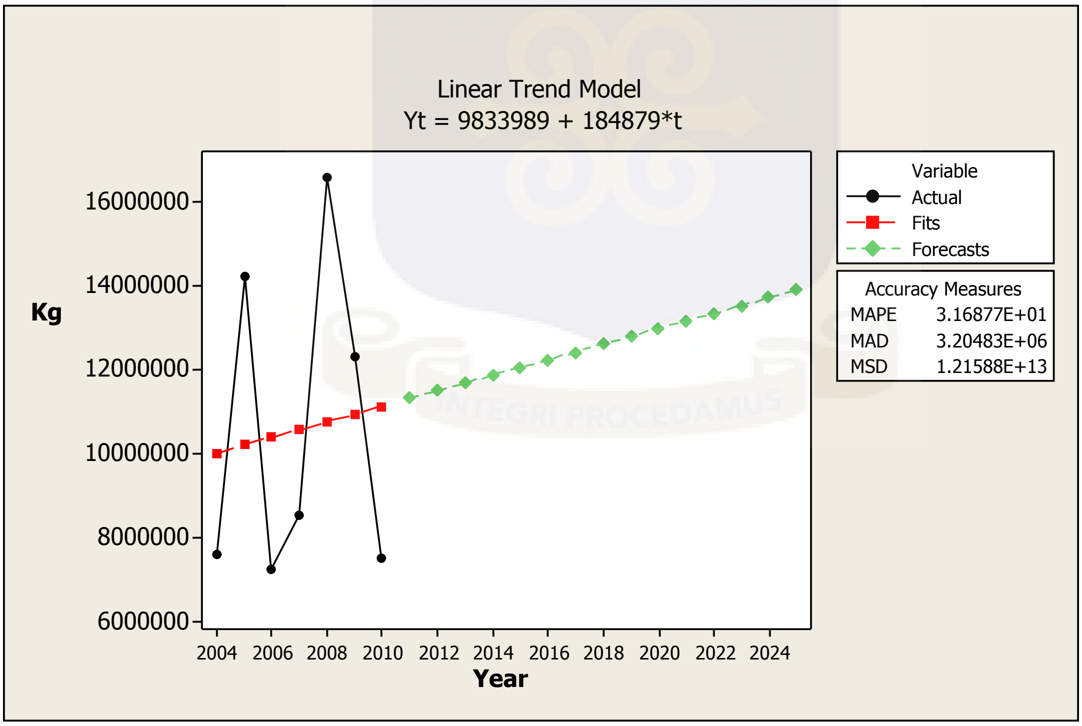
Source: Ghana CEPS (2010).

On the whole, approximately 74 million kilograms of used computers were imported into Ghana between 2004 - 2010. The highest (16, 603,317.00 kg = 22.4%) volume of import was recorded in 2008, and the lowest (7,255,473.00 kg = 9.8%) as observed in 2006 (Table 4.2). As shown in Table 4.2, import flow from 2004 to 2010 depicted a fluctuating trend. However, a consistent decrease in flow was observed from 2008 to 2010 (Table 4.2).

4.2.1. Future Trends in Import Volume of Used Computers

A trend analysis of the volume of used computers imports suggests that Ghana is likely to receive increased import flows of used computers in the coming years (as shown in Figure 4.2). Based on the 2004 to 2010 used computers import data, it can be projected that import traffic of used computers to Ghana is likely to increase steadily to about 12.05, 12.98 and 13.90 million kilograms in 2015, 2020, and 2025 respectively (Figure 4.2 and Table 4.3).

Figure 4.2: Trend analysis plot for used computer imports to Ghana.



Fitted Trend Equation: Yt = 9833989 + 184879*t.
Source: Data is based on 2004 - 2010 imports data, Ghana CEPS (2010); 2011 - 2025 Forecasts, Author's Fieldwork (2013).

Since, most importers rarely test the functionality of UEEE before shipment (UNEP, 2005; Oteng-Ababio, 2010; Grant and Oteng-Ababio, 2012), the results suggest that there is likely to be a corresponding increase in the annual volume of non-functioning used computer imports in the coming years. One can only estimate amount of e-waste flow due to lack of available data (Juan, 2009). It has been estimated that between 10 to 20% of second hand electrical and electronic products are broken and sent directly to the informal recycling sites (Amoyaw-Osei *et al*., 2011). However, should Ghana soon adopt proactive and effective e-waste management and shipment control mechanisms this scenario can be minimised or averted.

Table 4.3: Forecast Volume for Used Computer flows to Ghana, 2011 - 2025

Year	Forecast Import Volume (Kg)
2011	11,313,025
2012	11,497,904
2013	11,682,784
2014	11,867,663
2015	12,052,542
2016	12,237,422
2017	12,422,301
2018	12,607,181
2019	12,792,060
2020	12,976,940
2021	13,161,819
2022	13,346,699
2023	13,531,578
2024	13,716,458
2025	13,901,337

Source: Author's fieldwork (2013).

It must be noted that besides the importance of times series analysis in understanding and modelling the data, predicting of short-term trends from previous patterns, and identify patterns in correlated data, that is trend and seasonal variation, there are also some limitations associated with it. First of all, the use time series analysis for too small data results in higher error rate. Secondly, it is difficult to accurately predict since the data used is not monotonous. This may be due to the small data size. Finally, the prediction can only be applied for a short term.

4.3. Customs Clearance Procedure at the Tema Port and its Limitations

Every goods for import, including UEEE, have to pass through customs procedures for proper examination, appraisal, assessment and evaluation as part of the clearance procedure. This enables the custom authorities to charge the appropriate tax and also make sure the goods are not prohibited import (SBC, 2011). As most e-wastes are shipped across borders as used or second-hand equipment, either deliberately or unintentionally (SBC, 2011), this study examined the procedures for UEEE imports to be cleared through the Tema Port in order to identify possible challenges that may require attention.

This study found that various actors are involved in the clearance of goods at the port. The Customs Division of Ghana Revenue Authority (GRA) is the main authority in charge of verification and clearance of goods (including UEEE) at the Ghana ports. Customs, as part of its mandate derived from the CEPS Management law P.N.D.C.L 330 of 1993 undertakes valuation of certain category of goods and ensures that the appropriate duties and taxes levied by government on the imports (or exports) are collected.

Apart from Customs, the GPHA facilitates the physical clearance process and ensures collection of rent and handling charges. It provides the facility and platform for persons to import and clear their goods from the port. Other relevant stakeholders are the Ghana Standard Authority (GSA), Environmental Protection Agency, shipping lines, Destination Inspection Companies (DICs) and clearing agents. All these stakeholders play diverse roles for goods or UEEE imports to be cleared through the Tema port and work within a set of procedures and accompanying documentations.

Interviews with the port respondents indicated that, there are currently no specific guidelines for the importation of UEEE in Ghana. Thus, procedures for the importation of UEEE through the Port of Tema are not different from the import requirements for other classified high risk goods. Generally, to be able to import goods, including UEEE, the importer/clearing agent needs to obtain certain documents, including the original bill of lading (B/L), attested invoice and packing list from the shipping line which delivers the goods at the port on behalf of the importer.

The importer is also required to obtain a Final Classification and Valuation Report (FCVR) from an assigned Destination Inspection Company (DIC), a Tax clearance certificate (TCC) and Tax payers identification number (TIN) from the Customs Division of the Ghana Revenue Authority, an Import Declaration Form (IDF) from the Ministry of Trade and Industry, as well as register with and obtain relevant permits or licences from other relevant agencies including the Ghana Standards Authority and the Environmental Protection Agency (EPA). According to respondents from EPA, in the absence of requisite legislations, the EPA is currently creating a database of importers who import UEEE in commercial quantities.

According to the Customs officials, clearance procedures for goods import commence with the submission of manifest (which is a report designed to furnish particulars of the vessel, persons on board and general particulars of any cargo carried) by the shipping agency to Customs. This submission is conducted electronically and the manifest is integrated into the Ghana Community Network (GCNet) System. The GCNet is an innovative solution that has been designed to facilitate a fast and effective processing of Customs related operations, and comprises of a fully integrated customs management software/ system called Ghana Customs management system (GCMS) which has been connected over a network to the various stake holders working with Customs in the business of importing and exporting goods to and from Ghana. After the electronic submission through the GCNet, the shipping agent receives an automatic response. The importer/clearing agent or declarant can then submit a declaration against the manifest.

According to the port officials, all imports in commercial quantities are subjected to destination inspection unless exempted by the Ministry of Trade and Industries. Among the objectives of the destination inspection programme are to promote fair trade practices, ensure the availability of healthier and safer products on the market, and eliminate illegal importation of fake, adulterated, prohibited and/or inferior / shoddy goods by protecting the interest of the consumer. Therefore, depending on the country of origin of the imported UEEE (consignment), the importer/clearing agent submits the Import Declaration Form (IDF), Bill of Lading, Invoices and Packing List he/she had received from the shipping line, to an assigned Destination Inspection Company (DIC) for the issuance of a Final Classification and Valuation Report (FCVR). The DIC then authenticates the documents and subsequently issues the FCVR stating the value of the consignment and the duty payable.

However, the Customs respondents indicated that, the report is only an opinion of the DIC, and as the final authority, Customs may accept, reject or modify it as appropriate. It is worth mentioning that, apart from certain category of goods such as baggage and personal effects (Bona fide), diplomatic missions and other specified Government privileged persons Organizations and Institutions may enjoy exemption from payment of import duty and some other taxes (GRA,2011). This could create a pathway for abuse.

The interviews with the port respondents further indicated that, as part of the clearance procedure, the importer/clearing agent will after obtaining the FCVR, electronically submit a declaration through the GCNet to the Ghana Customs Management Systems (GCMS). The Customs Officials, detailed that, the importer /clearing agent or declarant declares the description and quantity of the UEEE he/she has imported and does a self-assessment of the duties and taxes involved. This is achieved by selecting the correct Harmonized System (HS) or commodity code and the customs procedure codes (or C.P.C). The commodity code selected determines the rate of duty applicable and the C.P.C modifies the rates and defines the procedure or duty treatment to be applied.

The Customs officials, however indicated that, importers sometimes abuse the opportunity of self-assessment of the taxes involved and under-declare and or misclassify their products so as the evade the payment of applicable taxes. According to SBC (2011), the volume of the trade in UEEE is not easily expressed in figures, because the declaration of it is carried out under a wide variety of labels. The labels range from 'used goods', 'household goods', 'goods for charity', 'mixed equipment' among others.

Customs, after receiving the declaration which was electronically submitted by the importer through the GCNet, validates and filters it through the selective or risk management module A response is then sent back to the importer / clearing agent or declarant, with the number of declaration and instruction to go and pay at the bank and to report to the long room to an assigned officer. It must be mentioned that, though the process of submission of the declaration and subsequent response to the importer/ clearing agent is electronically conducted and therefore expected to be completed in just some few minutes, the clearing agents claimed that, the GCNet system sometimes breaks down due to network connection problems among other technical challenges. This sometimes makes process take about several hours than usual, thus contributing to undue delay in the clearing process. The time lost can negatively affect the business of importers/clearing agents since it may consequently delay their intended period for distribution or sale of the imported goods.

The UEEE importer /clearing agent or declarant, after printing out the declaration (response) and making payment of the applicable taxes/duty at the appropriate bank (i.e. Ghana Commercial Bank (GCB) or ECOBANK), attaches the receipt, the bill of lading, attested invoice, IDF and FVCR as well as any relevant Ministry, Department and Agency (M.D.A) permit (previously obtained from the M.D.A (such as GSA and EPA) and reports to the long room to a Customs Compliance Officer instead of a Document Verification officer, because (U)EEE is classified as high risk goods requiring physical examination.

The Customs Compliance Officer then vets the declaration and accompanying supporting documents, which includes all relevant permits, to make sure that all requirements have been met by the declarant or importer. The Customs Compliance officer then sends the declaration electronically to a designated Customs Examination Officer for physical examination of the imported UEEE. This physical examination process, which is basically meant to determine whether the declared description and quantity agree with results of examination is described in detail in the next subsection.

After the UEEE imports have been physically examined by the Customs Examination Officer, officials from relevant MDAs (including GSA and EPA) also physically examine the goods at the container terminal, and if also satisfied, they endorse the relevant documents and give their approval before Customs can finally release the goods. Therefore, in the absence of any discrepancy, the Customs Examination Officer releases the consignment on the declaration (hard copy) and electronically sends via the GCNet to the GCMS that the electronic goods are released. However, in case of detection of any discrepancy such as under-declaration and/or misclassification, the importer or clearing agent/declarant is made to pay for the observed difference with a penalty payment not exceeding 100% of the applicable tax for the items before the goods are released by Customs.

After the release of the UEEE imports by the Customs Examination officer, a Delivery Tally Sheet or waybill is issued by the Shore Handling Service provider so as to allow for the loading of the goods onto a truck and exit the port. Prior to this, the importer / clearing agent must have already paid all necessary charges including to relevant service providers , including rent, administrative and handling charges, demurrage, and un-stuffing charges (where applicable). The importer/clearing agent then presents all clearing documents to the Customs Division of GRA at the exit gate to confirm (using the GCNet) whether the goods have indeed been released by them. Copies of waybill are then given to Ghana Ports and Harbours Authority (GPHA) Security and Police detailed at the gate to inspect and allow exit as appropriate.

4.3.1. Physical Examination of UEEE Imports at the Tema Port

(Used) electrical and electronic equipment imports fall under the category of goods that have serious health and safety implications on the consuming public (high risk goods). Thus, unlike other goods, such imports are subject to physical examination at the port. Goods in transit are however not subject to physical examination but are just sighted by Customs. Furthermore, unless there is need for suspicion, imports by diplomatic missions and other specified Government, privileged persons, Organizations/Institutions are exempted from physical examination and these could be possible pathways for abuse.

Physical examination of imported UEEE items is conducted at the Port's container terminals. This involves the crosschecking of the container number and seal by the Customs examination officer to ensure that prior to opening, the container is the right one to be inspected and the seal has not been tampered with, the opening of the container by the terminal operator in the presence of the Customs examination officer and the importer/clearing agent, the unpacking of the electronic items from the container and sorting according to types (shown in Plate 4.1) by the importer/clearing agent, and the visual inspection of the UEEE quantities, sizes, and product labels (such as the brand, volume, weight, voltage) by the regulatory officials to ensure that the description, standards (if any),

container. This, according to the regulatory officials, makes the work very cumbersome and tedious. The congestion / lack of adequate space at the container terminals also slows down the process of physical examination and thus, adds to the delay in the clearance process. In cases of imports of large consignments, regulatory officials indicated that they have no choice but to randomly sample the imported items in the container for inspection to avoid so much delay.

Secondly, though the physical examination is expected to be done by Customs and the relevant MDAs concurrently so as to facilitate the process, it was observed during the port visit that, almost all the time, Customs examination officials first conduct their physical examination of the imported items, after which, the importer/agent goes and calls the other needed enforcement officials from EPA and GSA to also come and conduct visual examination of the same items before they cleared. This separate inspection of the same item at different times, also leads to undue delay in the clearance process and could be attributed to the fact that, the enforcement agencies at the port are inadequately and unequally resourced with regard to logistics and personnel. For instance, the Customs Division of GRA has more personnel at the Tema Port than the GSA who also have relatively more personnel than the EPA at the port.

Thirdly, the enforcement officials indicated that, at times some of the imported UEEE have their product labels missing or removed and this makes it quite difficult for them to determine if they are the correct products declared. According to them, it takes experience and technical knowledge in these electronic products so as to correctly determine for instance, the sizes, volume or voltages of products with missing labels.

Fourthly, it was observed that, there are no available designated sheds for UEEE imports inspections at the container terminals in the port. Therefore, the imported second hand electronic items are unpacked from the containers and placed on the ground, in the open air. This practice exposes the imported items, examination officers, as well as importers/clearing agents to the vagaries of the weather, and can possibly also lead to the damaging of some the electronic items especially on rainy days and render them non-functional. Furthermore, though currently not mandatory because of the absence of national e-waste law, there is presently no available equipment at the port for the sole purpose of testing the functionality of UEEE imports.

Lastly, it was observed during the field visit that, regulatory personnel do not take into consideration adequate safety measures during physical examination of UEEE imports. For instance, though containers could be fumigated or contain radioactive materials (SBC, 2011), neither fumigation nor radioactive test were conducted before opening containers. This could pose health risk to personnel at the port. Furthermore, safety chains were not mounted when opening the doors of containers loaded with imported UEEE. Containers can sometimes be loaded on their backside, making it possible for imported items to fall out when opening these containers without safety chains (SBC, 2011), and thus pose the risk of physical injury and damaging of the imported items.

It was observed that, the only personnel safety equipment which were being used by almost all enforcement personnel at the container terminals were reflecting clothes and safety shoes. Only very few personnel wore helmets and none were observed using gloves during the physical inspections of the UEEE imports at the port terminals. The non-use of these personal safety items can also expose enforcement personnel to injuries. One Customs examination officer for instance, complained of having sustained a cut injury on the hand during container inspection at the port. One possible contributing factor for the failure of the regulatory officials to adhere to adequate safety procedures during physical examination of goods /

containers at the port could be due to inadequate provision of personal safety equipment for enforcement personnel at the port.

It must however be mentioned that, despite the limitedness and inequality in resource availability at the relevant regulatory agencies at the port, there is some level of collaboration between enforcement agencies with regard to UEEE imports examination, but there is the need for strengthening. The regulatory officials indicated that in special instances when a container has been tagged for inspection by Interpol , there is a Joint Port Container Unit (JPCU) which works together to do the inspection. The JPCU comprises the Police, Customs, National Security, EPA and Narcotics Unit.

4.4. Quality of UEEE imports through Tema port

A cursory observation of some of the UEEE cleared at the port during the field visits showed that some of the items looked quite good and clean. However, others looked old and in bad shape, with some parts missing or broken at the time of clearing, and hence may not be functioning. Nonetheless, the functionality of these items can only be proven by a system of testing samples of the UEEE that come through the port. According to the Basel Convention's draft technical guidelines on the transboundary movement of UEEE and e-waste, UEEE would normally be considered waste if it, among other defects, is not complete - essential parts are missing; shows physical damage that impairs its functionality or safety; old or out-dated or appears particularly worn or damaged, thus reducing its marketability (SBC, 2011). Though party to the Basel Convention, the Convention is presently not binding on Ghana as the State is yet to domesticate the provisions of the Convention into its national laws.

Issues of quality fall within the domain of the Ghana Standards Authority (GSA) who incidentally only check on the quality of new EEE imports since there are no applicable standards for testing the quality of second hand electrical and electronic equipment. As one respondent from GSA explained:

> *It is difficult and almost impossible to set standards for testing the quality of UEEE because so many variables, such as differences in period of usage and so on, may have to be taken into consideration. So officials use a lot of discretion in determining the quality of such products, and this is subjective.*

This indicates that experience and credibility or integrity of regulatory officials are crucial for physical examination of UEEE imports. According to most of the regulatory respondents involved in this study, UEEE imports arriving at the Tema port are mostly obsolete and mainly non-functional. As one regulatory official remarked:

> *A lot are junks, they are not supposed to be brought in, especially these computers and monitors, but people buy them, so they bring them and pay the duty.*

Although the importers and clearing agents involved in this study confirmed that very often, some of the UEEE imports are not in good working condition upon arrival because importers hardly check the functionality of these electronic items before shipping to Ghana, they further argued that, some of their products get damaged during shipping and handling processes at the ports. One of the respondents illustrated this by remarking:

> *There is no guarantee that the goods arriving will work. The shaking of the ships during transport sometimes causes some of the electronic products to get damaged. Sometimes the items also get damaged during unloading from the container. Some of the products do work, but majority do not work when we switch them on, until they are repaired. Most often, the faults are minor and can be repaired. However, some of the products also arrive with some parts missing, and even though they can be repaired, the parts needed for the repairs are not available so we sell them to scrap dealers.*

Second hand electrical and electronic equipment that have no regular market or are destined for disposal instead of reuse are normally considered to be e-waste (SBC, 2011). The Basel Convention stipulates the conditions under which transboundary movement of hazardous wastes can be permitted among Parties. Among these conditions, transboundary movement of hazardous wastes can only be permitted if the country of export does not have the technical capacity and the necessary facilities to dispose the wastes in question in an environmentally sound and efficient manner, or, if the treatment in the country of import or final destination will be managed in an environmentally sound manner. This suggests that, though the Basel Convention is currently not in force in Ghana because the country is yet to domesticate the provisions of the Convention, the exportation of defunct UEEE from developed Parties such as the United Kingdom, the Netherlands, Germany and Italy which are capable of managing such items in an environmentally sound manner, is in contravention to the provisions of Basel Convention.

Very often, the importers, some of who reside or have relations abroad, sell the imported second hand electronic products as untested equipment to retailers who in turn, sell some of these electronic products as "untested products" or get them tested and repaired before selling to consumers. This finding corroborates Ayodeji (2011) study report in the Nigeria second hand electronic market. One of the respondents who has been importing UEEE for the past 4 years said this:

> *I have an elder brother outside who sends down the goods to me. The goods were previously not tested before shipment, but according to my brother, now the goods are tested before shipment. So I sell them at relatively cheap price without testing, and make the buyer aware that the products are untested. The customers buy it at their own risk. In case a buyer insists that I test it for him/her, then if am selling the untested goods for example 100 Ghana cedis ($33.00), I will explain to the buyer that,*

if I test, I will increase the selling price to about 110.00 Ghana cedis ($37.00) or 140.00 Ghana cedis ($47.00).

Thus, untested UEEE products at the market are sold at relatively cheaper prices than the tested ones. Plates 4.2 and 4.3 show some imported sound systems, TV and Fridges on sale at the Tema Community One second hand electronic market. During the field visit at the Tema Community One second hand electronic market, one retailer who has been in the business for over 20 years confirmed that the importers import the second products without any testing and sell it as such to them (retailers). She considered the second hand electronic business to be 'try your luck' and said that:

When we buy the untested products from the importers, we then test and separate those that are working from the non-working ones. For instance, yesterday 55 kettles were delivered to me and 15 were not working. So I will now look for an electrician to see if it is repairable. For those that are not repairable I give them to Scrap dealers at a lower price. The work is profit and loss.

Plate 4.2: Used televisions and sound systems at the Tema Community One second hand electronic market.

Source: Author's field work (2013).

Plate 4.3: Used refrigerators on sale at Tema Community One second hand electronic market.

Source: Author's fieldwork (2013).

Most e-wastes are transported across borders as used or second-hand equipment, either deliberately or unintentionally (SBC, 2011). The shipments of obsolete UEEE to most developing countries as "equipment for reuse" is due to inadequate enforcement of the related transboundary regulation in both the countries of origin and the countries of destination (Ayodeji, 2011). The Basel Convention prohibits the shipments of hazardous wastes such as obsolete UEEE from member states to developing countries and countries with economies in transition, but also contains a number of loopholes (Clapp, 2002; Osibanjo, 2010a).

According to the Basel Convention, wastes are those substances or objects disposed of, intended to be disposed of, or required to be disposed of under provisions of national law. However, because the Convention covers wastes being transported for resources recovery, recycling, reclamation, direct re-use or alternative uses, constituents of such wastes may cease to be wastes and become products after completion of the disposal process (Osibanjo, 2010a).

Ghana is a party to the Basel Convention, but as a dualist State, the Convention is not binding on the Ghana until Parliament or Government of Ghana transposes its provisions into national laws. That notwithstanding, Article 36(9) of the 1992 Constitution of Ghana, as well as the National Environmental Policy enjoins the State to take appropriate measures to control pollution and the importation and use of potentially toxic substances. Ghana's Draft Bill on Hazardous and Electronic Waste Control and Management will seek to domesticate the Basel and Bamako Conventions and control e-waste imports and management in Ghana.

4.4.1. Socio-Economic Implications of UEEE Imports

Based on the results, it is evident that the importation of UEEE, irrespective of whether it is functioning or obsolete, contributes to national economy. Besides the revenue that government generates by way of duty paid on importation of some of the second hand electrical and electronic equipment such as microwaves and televisions, the interviews with importers, clearing agents and retailers of UEEE also indicated that the importation and subsequent sale of these imported items which includes used computers, whether tested or non-tested, is a good source of revenue generation to them, and also offers some form of economic benefits to consumers since such products are relatively less expensive. Notably, the importation of some of the UEEE such as computers enjoy a free-import duty regime in Ghana, thus, further enhancing the import trade (Amoyaw-Osei *et al,* 2010; Oteng-Ababio, 2012).

The study further shows that, though importers and retailers of UEEE are sometimes faced with the risk of making a loss or relatively lower profit from untested UEEE imports which might not be functioning upon arrival, the subsequent release or sale of the non-functioning or obsolete UEEE to workers lower down the UEEE / e-waste chain such as refurbishers for repairs, or to e-waste scavengers and recyclers if beyond repairs, also afford these workers, who are largely youth, with low level of education and therefore may not be able to find work in the formal sector, a means of making income from the recovery and sale of some of the obsolete UEEE valuable materials including copper and iron. However, as noted by Prakash *et al*. (2010) although end-of-life treatment operations of e-waste lead to further employment and income opportunities for a large group of people, they are also associated with severe environmental and health hazards, hence diluting the overall potentials and benefits to a large extent.

4.5. The Pollution Haven Hypothesis and International E-waste flow to Ghana

The pollution haven hypothesis provides possible explanation for the international shipments of e-waste (Lepawsky and McNabb, 2010) to Ghana. The hypothesis posits that pollution-intensive economic activity will tend to migrate to those jurisdictions where costs related to environmental regulation are lowest (Lepawsky and McNabb, 2010).

As indicated earlier in this study, most of the import flow of second hand used computers and by implication e-waste to Ghana, are transported from Europe and North America where environmental regulations are relatively stringent. This suggests that the lack of national e-waste legislation and the weak enforcement of existing national laws relating to e-waste importation and management in Ghana such as the Energy Efficiency Regulations, 2008, and the Environmental Protection Agency Act, 1994 (Act 490) could be major plausible reasons for the large share of import flow from these developed regions. Furthermore, the combat against the e-waste menace in Ghana has been given very low priority by Government.

According to Neumayer (2001), the most important factor that could lead to pollution havens is that developing countries might suffer from political institutional deficiencies that could create a bias against environmental preferences such that their environmental standards are set inefficiently low or are not enforced. That notwithstanding, there are several other variables besides environmental regulations which affect trade. As suggested by Lepawsky and McNabb (2010), it is essential to examine trade transactions based on the relationship between a given importing country's GDP per capita and the GDP per capita of its trade partner(s).

In this study, it was also found that, remarkably, out of the total of about 7.5 million kilogram of used computers imported into Ghana in 2010, about 7.4 million kilogram (98.7%) were from not less than 59 countries whose GDP are relatively higher than Ghana's (Appendix D2). This suggests that the majority of e-waste imports to Ghana were from countries relatively richer and developed than Ghana. These countries include the United Kingdom, the United States of America, Italy, Germany, France, Netherlands, Belgium, China, United Arab Emirates, Denmark, Lebanon, Japan, Spain, Sweden, Malaysia, Brazil, India, Saudi Arabia, Indonesia, Israel, South Africa and Nigeria. Notably, import flow from the UK (approximately 2.8 million kilogram) and USA (about 1.4 million kilogram) together accounted for more than half of the total volume (about 7.5 million kilogram) of imports in 2010 (Ghana CEPS, 2010).

The large percentage of imports to Ghana from the relatively rich countries supports the supposition that countries with lower GDP per capita would be in greater need of foreign investment and thus more likely to accept polluting industries like e-waste recycling (Lepawsky and McNabb, 2010). As Lepawsky and McNabb (2010) simply put it, as GDP per capita decreases, the likelihood of a given country being a net importer of e-waste increases. However, it was also noticed that about 1.27% of the volume of imports in 2010 were from countries with relatively lower GDP (less than 32,520.00 million US Dollars) than Ghana’s, such as Cyprus, Panama, Bahrain, Netherlands Antilles, Jordan, Senegal, Burkina

Faso, Cote d'Ivoire, Sierra Leone, Togo, Niger, Mauritius, Kenya, Botswana, Republic of Djibouti, Republic of Uganda, Tanzania, Gabon, and the leading exporter from the Africa, Guinea (Appendix D2).

The import flow from the relatively poorer countries, thus indicate that the pollution haven hypothesis could only be partially applicable with regard to international shipments of e-waste to Ghana. In this regard, this study therefore agrees with Lepawsky and McNabb (2010) study report on international flows of electronic waste, in which they found that the international trade in e-waste is a more complex issue than being one about 'rich' countries dumping waste in 'poor' countries, and that while e-waste is transported from developed to developing countries, there is a substantial trade in e-waste between developing countries and therefore the pollution haven hypothesis is an important, but partial, explanation of observed trade patterns in e-waste.

The limitations surrounding the utility and evidence of the pollution haven hypothesis have been cited in several studies (Birdsall and Wheeler, 1993; Neumayer, 2001; Wheeler, 2001; Clapp 2002, Cave and Blompist, 2008; Lepawsky and McNabb, 2010). According to Lepawsky and McNabb (2010), as literature on the PHH is largely focused on production, it misses key aspects of consumption, waste processing and disposal that nevertheless have pollution effects. The pollution haven hypothesis may be both empirically and conceptually limiting in terms of understanding the realities of the trade and traffic of electronic waste Lepawsky and McNabb (2010).

4.6. E-waste Handling Activities at Selected E-Waste Sites

Obsolete electrical and electronic equipment, regardless of whether they are domestically generated or imported, often end up at open dumpsites or scrap yards as Ghana lacks a well-established formal e-waste management system. Thus, e-waste is predominantly managed by the informal sector who use simple tools and rudimentary methods to recover valuable e-waste materials for sale (Prakash *et al*., 2010, Amoyaw-Osei *et al*., 2011, Grant and Oteng-Ababio, 2012). This suggests that, but for the informal sector, precious materials (such as gold, copper and aluminium) from most of the imported or domestically generated obsolete UEEE or e-waste may have remained unrecovered or lost.

A number of studies have documented the processes of e-waste management by the informal sector in Ghana (Brigden *et al*., 2008, Prakash *et al*., 2010, Amoyaw-Osei *et al*., 2011, Grant and Oteng-Ababio, 2012). Basically, informal e-waste activities in Ghana include the collection, refurbishment, recycling and disposal of residuals or non-valuable e-waste fractions (Prakash *et al*., 2010, Amoyaw-Osei *et al*., 2011, Grant and Oteng-Ababio, 2012). The field study revealed that, the collection of e-waste (for example, from private homes and offices) to e-waste sites for recycling was a common practice engaged in by e-waste workers at all the three e-waste sites in this study. Handcarts are used (pulled by the e-waste collectors) to transport the collected e-wastes to the e-waste sites for processing. According to Prakash *et al*. (2010) such a rigorous activity often leads to spinal injuries and back pains due to lifting and transportation of heavy equipment, and consequently to a relatively short career spanning not more than 6 –7 years.

Another common e-waste processing activity observed at all the three e-waste sites in this study was the manual dismantling of e-waste. It was observed during the field survey that generally, in their quest to recover precious e-waste materials like copper and aluminium, e-waste workers use rudimentary tools such as hammers and chisels to manually dismantle obsolete computers, refrigerators, and televisions (Plate 4.4). None of the e-waste workers at

Previous studies in Ghana have reported that, at times, some of the e-waste residues such as low grade printed wiring boards (PWB) are burnt to reduce the e-waste volumes on the uncontrolled dumpsites (Brigden *et al*., 2008, Prakash *et al*., 2010, Amoyaw-Osei *et al*., 2011). Usually, insulating foam, primarily polyurethane (PUR), from obsolete refrigerators, and automobile tyres, are used as co-fuel to sustain the fires used for burning cooling grills of air conditioners (Brigden *et al*., 2008, Prakash *et al*., 2010).

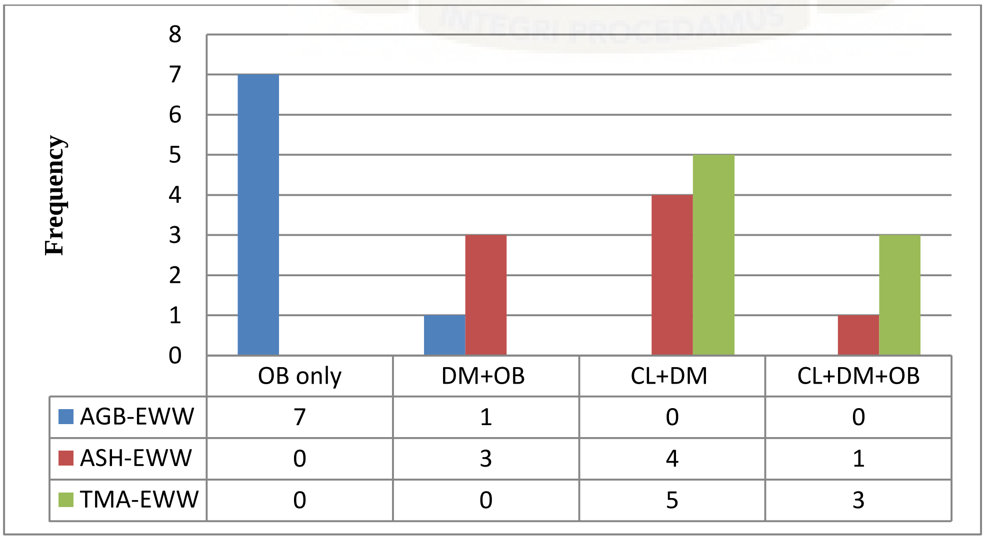
Unlike the Agbogbloshie and Ashaiman e-waste sites, the field survey revealed that, the onsite open burning and disposal of e-waste is currently not being carried out at the Tema Community One Market e-waste site included in this study. According to the e-waste workers at Tema e-waste site, some of them transport certain e-waste components to their respective homes or to the Agbogbloshie site in Accra, to be openly burnt to recover valuable materials. The Tema e-waste workers explained that, their reason for not burning e-waste at the site was because they fear being ejected from the place by the TMA, whose officials frequently visit the Tema Community One Market to perform various assigned duties including monitoring. It must be mentioned that the TMA Head office is actually located close to the Community One Market Area at a place popular called 'Centre'.

The field survey further revealed that, unlike the Agbogbloshie and Ashaiman, the workers at the Tema e-waste site usually clean up (sweep) the site after close of work and dispose of any non-valuable e-waste fractions into the public waste container which is located at a place near the e-waste site in the Tema Community One Market. The socio-economic benefits of informal e-waste management in Ghana have been highlighted in a number of studies (Oteng-Ababio, 2011; Prakash *et al*., 2010). Despite the positive impacts with regard to employment creation and significant contribution to the national economy (Prakash *et al*., 2010), the current e-waste management practices have been characterised by processes which lead to environmental pollution and exposes workers and the general public to health risks (Brigden *et al.*, 2008, Asante *et al.*, 2012, Caravanos *et al.*, 2013).

Figure 4.3 and Table 4.4, respectively show the distribution of e-waste participants by the kind of e-waste processing activity they are involved in, and number of working years in the e-waste business. In general, nine (37.5%) out of the twenty-four e-waste participants claimed they were engaged in both e-waste collection and dismantling (Figure 4.3). Seven (29.2%) claimed they are engaged in solely open burning activities. Four out of the twenty four e-waste participants said they are involved in both dismantling and open burning of e-waste.

The remaining four of the twenty-four e-waste participants claimed they are engaged in all three e-waste activities (i.e. collection, dismantling and open burning) (Figure 4.3). Majority (seven out of eight) of the e-waste participants at the Agbogbloshie e-waste site claimed they engage in solely open burning of e-waste. Most of the e-waste participants at the Ashaiman (four out of eight) and Tema (five out of eight) e-waste sites claimed they have been engaging in both e-waste collection and dismantling activities (Figure 4.3).

Figure 4.3: Distribution of e-waste workers by e-waste handling activities.



	OB only	DM+OB	CL+DM	CL+DM+OB
AGB-EWW	7	1	0	0
ASH-EWW	0	3	4	1
TMA-EWW	0	0	5	3

OB = Open Burning; DM = Dismantling; CL = Collection. Source: (Author's fieldwork (2013).

In terms of number of years of engagement in e-waste related activities, Table 4.4 below shows that, in general, only few (4 out of 24) of the e-waste participants in the Accra-Tema Metropolis have been engaged in the business of e-waste for over 10 years now. The majority (20 out of 24) of the e-waste participants have been engaged in e-waste business for less than 7 years. Prakash *et al*. (2010) notes that, as a result of the rigorous nature of the e-waste activities which includes the lifting and transportation of heavy appliances which lead to injuries and back pains, the career of e-waste collectors is relatively short, spanning not more than 6 - 7 years.

Table 4.4: Distribution of e-waste participants by e-waste working experience

Work Experience	**Agbogboshie E-waste Workers**		**Ashaiman E-waste Workers**		**Tema E-waste Workers**	
Years	Frequency	%	Frequency	%	Frequency	%
1-3	4	50	4	50	2	25
4-6	4	50	3	37.5	3	37.5
10+	0	0	1	12.5	3	37.5
Total	**8**	**100%**	**8**	**100%**	**8**	**100%**

Source: Authors Fieldwork (2013)

The results show that, the mean period of time that the 24 e-waste participants involved in this study, have been engaged in e-waste business was 5.2 years, with a range of 1 to 17 years. Notably one of the e-waste participants at Ashaiman e-waste site and another one at the Tema e-waste site have been dealing in e-waste for the past 14 and 17 years, respectively (Appendix E2). Caravanos *et al.* (2013) in their exploratory health study at the Agbogbloshie e-waste site observed that, the mean period of time that the participants had been involved in e-waste recycling was 7.8 years, with a range of 1 to 33 years.

Comparatively, the results indicated that e-waste participants at the Tema e-waste site (mean: 7.1 years), followed by those at the Ashaiman e-waste site (mean: 4.9 years) have been have been in the e-waste business for a relatively longer number of years than the e-waste participants at the Agbogbloshie e-waste site (mean: 3.6 years). This thus suggests that, there are relatively more new entrants in the business of e-waste processing at the Agbogbloshie e-waste site than at the Ashaiman and Tema e-waste sites. As mentioned in chapter three, none of the subjects from the control group engages in any e-waste business activity.

4.7. Socio-Demographic Characteristics of Respondents

Table 4.5 presents the background information of e-waste workers and control group involved in this study. The data showed that all the 24 e-waste workers involved in this study were males with ages varying from 12 to 30 years. This agrees with similar findings at the Agbogbloshie e-waste site that the informal e-waste sector are dominated by males who are mostly youth (Brigden *et al.*, 2008; Amoyaw-Osei *et al.*, 2010; Prakash *et al.*, 2010; Oteng-Ababio, 2011; Caravanos *et al.*, 2013). The dominance of males in the informal e-waste sector could be ascribed to the rigorous nature of the e-waste processing activities such as the as manual dismantling e-waste with harmers and chisels, and the lifting of weighty obsolete electrical and electronic equipment.

In general, most (11 = 45.8%) of the 24 e-waste participants were found to be within the age group of 20 to 24 years. Table 5.3 shows that two out of the eight participants at the Agbogbloshie e-waste site were children within the age group of 10 to 14 years. The remaining 6 participants from the Agbogbloshie e-waste site were had ages between 15 to 24 years. Majority (4 = 50%) of the participants at the Ashaiman e-waste site happen to fall within the age group of 20 – 24 years, and none was or below the age of 14 years (Table 4.5). It can be noticed in Table 4.5 that four of the participants from the Tema e-waste site fall within the age group 20 – 24, and the remaining four were within the age group of 25 – 29 years. This suggests that e-waste workers at the Tema e-waste site are predominantly young adults.

Table 4.5: Background information of participants involved in urine sampling

	Agbogboshie E-waste Workers		Ashaiman E-waste Workers		Tema E-waste Workers		Mataheko Control Group	
Variable	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Age (years)								
10 -14	2	25	0	0	0	0	2	25
15 - 19	3	37.5	2	25	0	0	0	0
20 - 24	3	37.5	4	50	4	50	1	12.5
25 - 29	0	0	1	25	4	50	3	37.5
30 and above	0	0	1	0	0	0	2	25
Total	**8**	**100%**	**8**	**100%**	**8**	**100%**	**8**	**100%**
Sex								
Male	8	100	8	100	8	100	6	75
Female	0	0	0	0	0	0	2	25
Total	**8**	**100%**	**8**	**100%**	**8**	**100%**	**8**	**100%**
Education								
Primary	2	37.5	3	50	2	25	1	12.5
J.H.S	2	12.5	2	25	3	37.5	1	12.5
S.H.S	1	12.5	1	12.5	2	25	2	25
Tertiary	0	0	0	0	0	0	4	50
Non-formal	3	25	2	12.5	1	12.5	0	0
Total	**8**	**100%**	**8**	**100%**	**8**	**100%**	**8**	**100%**
Region of Hometown								
Northern	6	75	7	87.5	8	100	0	0
Upper East	1	12.5	1	12.5	0	0	0	0
Upper West	1	12.5	0	0	0	0	0	0
Greater Accra	0	0	0	0	0	0	8	100
Total	**8**	**100%**	**8**	**100%**	**8**	**100%**	**8**	**100%**
Current Residence								
Agbogloshie	8	100	1	12.5	3	37.5	0	0
Ashaiman	0	0	7	87.5	0	0	0	0
Tema	0	0	0	0	5	62.5	0	0
Mataheko	0	0	0	0	0	0	8	100
Total	**8**	**100%**	**8**	**100%**	**8**	**100%**	**8**	**100%**

Source: Author's Fieldwork (2013).

The mean age of all the e-waste workers from the Accra - Tema Metropolis was approximately 22 years, suggesting that the processing of e-waste provides a livelihood opportunity for especially the youth in the Accra-Tema Metropolis. The e-waste participants from the Tema e-waste site (age range: 20 - 28; mean 24.4 years), followed by those from the Ashaiman e-waste site (age range: 18 - 30; mean: 22.5 years) were found to be relatively older (in terms of age) than those from the Agbogbloshie e-waste site (age range: 12 - 24; mean age: 17.8 years). This suggests that, there could be relatively younger people entering into the business e-waste processing at the Agbogbogblo e-waste site than any of the other e-waste sites under this study, which could be perhaps Agbogbloshie is the hub of e-waste processing in Ghana.

The mean ages recorded for the e-waste participants from the three respective e-waste sites under this study were lower than that observed in similar studies by Asante *et al.* (2012) (mean: 27 years) and Caravanos *et al*., (2013) (mean: 32 years). However, it important to also note that the ages, as claimed by most of the e-waste workers were quite doubtful, especially so for the Agbogbloshie e-waste workers, since majority claimed they do not know their specific date of births, but were able to give their ages. The ages of the control participants ranged from 11 to 52 years, with a mean age of 26.4 years. It can be noticed in Table 4.5 that majority of the participants from the control group fall within the age group of 25 to 29 years. Two out of the 8 subjects in the control group were females and the rest were males.

Regarding education level, Table 4.5 shows that generally, the e-waste participants are less educated compared to the control participants. This suggests why e-waste processing has become a livelihood opportunity for people in the informal sector as they may find it difficult to find work in the formal sector. Whereas, all the control participants have had some form of formal education, six (25 %) out of the twenty four e-waste workers have had no formal education. Table 4.5 shows that unlike the control group, none of the e-waste participants involved in this study have attained tertiary level education. Generally, most (10 = 41.7%) of twenty four e-waste participants have attained secondary level of education (Junior and Senior High School) (Table 4.5). Comparing the level of education among e-waste participants, it can be noticed in Table 4.5 that the Tema e-waste participants appear to be more educated than those from the Agbogbloshie and Ashaiman e-waste sites.

As shown in Table 4.5, majority (21 = 87.5%) of the 24 e-waste participants involved in this study were from the Northern Region of Ghana. It can be noticed in Table 4.1 that, two of the participants (one each at Agbogbloshie and Ashaiman e-waste sites) come from the Upper East Region. The only e-waste participant (1 = 12.5%) observed to have migrated from the Upper West Region happens to be a worker at the Agbogbloshie e-waste site (Table 4.5). This result is thus in line with observations made by Grant and Oteng-Ababio (2012) that citizens from the three northern regions of Ghana were the most highly represented group in the country's e-waste economy.

Table 4.5 shows that all the eight e-waste participants at the Agbogbloshie e-waste site involved in this study have their current residences around their place of work (i.e. Agbogbloshie). Unlike the case of these Agbogbloshie e-waste workers, only 5 (62.5%) of the Tema e-waste workers and 6 (87.5%) of the Ashaiman e-waste workers have their domiciles in Tema and Ashaiman respectively. The remaining respondents working at the e-waste sites at Tema (3 = 37.5%) and Ashaiman (1 = 12.5%) all have their current place of residence to at Agbogbloshie in Accra. This confirms Agbogbloshie as the hub of informal e-waste recycling in Ghana.

The Tema and Ashaiman e-waste workers who have their domiciles at Agbogbloshie revealed that, their decision to move and work at Tema and Ashaiman e-waste sites is because Agbogbloshie is relatively congested with a lot of e-waste workers. This congestion, according to them, as resulted in increased competition for e-waste collection in Accra. Notably, the two most experienced e-waste workers (in terms of number of e-waste working years) at the Tema (17 years) and Ashaiman (14 years) e-waste sites both happen to have their current residences at Agbogbloshie in Accra. All the respondents in the control group were from the Greater Accra Region and reside at Mataheko, about 3km from Agbogbloshie in Accra.

Table 4.6: Distribution of respondents by alcohol consumption and smoking habits

	Agbogboshie E-waste Workers		**Ashaiman E-waste Workers**		**Tema E-waste Workers**		**Mataheko Control Group**	
Variable	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Alcohol Drinking								
Yes	2	25	0	0	1	12.5	2	25
No	6	75	8	100	7	87.5	6	75
Total	**8**	**100%**	**8**	**100%**	**8**	**100%**	**8**	**100%**
Smoking Habits								
Yes	8	100	1	12.5	5	62.5	0	0
No	0	0	7	87.5	3	37.5	8	100
Total	**8**	**100%**	**8**	**100%**	**8**	**100%**	**5**	**100%**

Source: Author's Fieldwork (2013)

Regarding smoking habits, Table 4.6 indicates that whereas none of the control participants are smokers, most of the e-waste participants (14 (58.3%) out of 24) involved in this study are generally cigarette smokers. All the e-waste participants at Agbogbloshie and Ashaiman e-waste sites are smokers and non-smokers respectively (Table 4.6). Only three out of the eight participants from the Tema e-waste site claimed to be non-smokers. For alcohol consumption, it was observed that similar to the control participants, most (21 = 87.5%) of the 24 e-waste participants involved in this study claimed they do not drink alcohol. Of the three alcohol consuming e-waste participants, two were from the Agbogbloshie e-waste site and remaining one was from the Tema e-waste site (Table 4.6). Possible influence of participant's alcohol consumption/smoking habits on their urinary heavy metals levels is discussed in chapter five.

4.8. Summary

This chapter presented and analysed the data on the flow and management of UEEE imports to Ghana, and discussed the results from the interviews and observations made at the port and e-waste sites. It was found that volume of used computers is likely to increase in the near future. Used computer imports, and by implication e-waste, are from both developing and economically developed regions. However, the majority of such imports are from Europe and North America. Thus, this study found partial support for the pollution haven hypothesis with regard to import flow of e-waste to Ghana.

Just like other goods, used electrical and electronic equipment imports have to pass through customs procedures for proper examination, appraisal, assessment and evaluation as part of the clearance procedure. Enforcement agencies at the port are inadequately and unequally resourced with regard to logistics and personnel, and this to some extent, contributes to delays in the clearance process. Not all UEEE imports are in good working condition upon arrival at the port. Importers and retailers often give out their damaged or irreparable UEEE to informal e-waste workers who make a living from the extraction of valuable materials from obsolete EEE without due regard to human health and environment. The next chapter discusses the environmental and biological sampling analysis and findings.

CHAPTER FIVE

EXTERNALITIES OF THE CURRENT E-WASTE MANAGEMENT PRACTICE

5.1. Introduction

This chapter engages with some of the externalities of the current management practices. It presents the results and analysis of the environmental and biological sampling and discusses the implications the current e-waste management practices on environment and human health. To assess the potential environmental and health challenges associated with the current e-waste management practices, this study analysed the concentrations of heavy metals in soil from selected sites, and in urine of e-waste workers and a control group. Currently, the Ghana EPA neither has standard values for heavy metals in soil nor reference values for heavy metals in urine. Therefore, the concentrations of heavy metals in soil from the selected sites were compared to the Dutch standard values for heavy metals in soil. The Dutch Target Value is based on potential risks to ecosystems, while the Intervention Value is based on potential risks to humans and ecosystems.

5.2 Analysis of Heavy Metals Concentrations in Soils

As indicated in Chapter Three, analytical quality was assessed using a certified reference material IAEA - Soil 7 (from International Atomic Energy Agency, Vienna, Austria). Table 5.1 shows the results of the certified reference material IAEA - Soil 7 that was analysed along with the analytical samples. Recoveries of the measured elements ranged from 85.38% to 100.27% of the certified values as shown in Table 5.1. The results for the analytical samples show that in general, the soil samples from the control and e-waste sites recorded relatively high Pb (range: 2.60 - 265.03 mg/kg), Sb (range: 2.57 - 178.29 mg/kg) and Cu (range: 2.63 - 99.93 mg/kg) concentrations compared to the other metals analysed in this study.

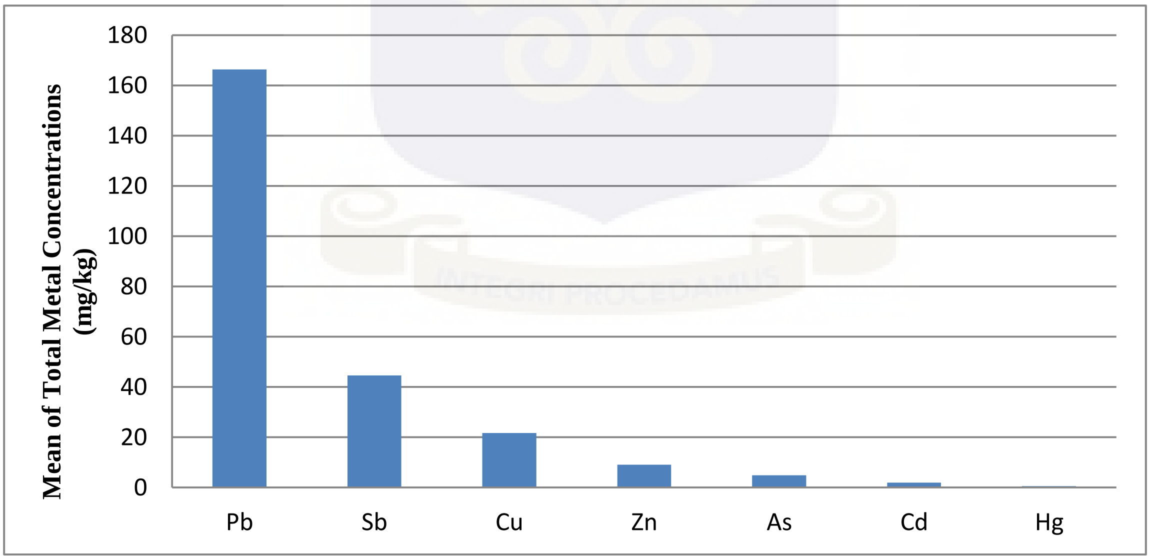
Table 5.1: Quality Assurance/Quality Control of IAEA - Soil 7 reference material and laboratory/ measured results

Metal	IAEA - Soil 7 Reference material results (mg/Kg)	Measured Value (mg/Kg)	% Recovery
Cu	11	11.03	**100.27**
Zn	104	102.3	**98.37**
Sb	1.7	1.62	**95.29**
Pb	60	57	**95.00**
As	13.4	13.05	**97.39**
Cd	1.3	1.11	**85.38**
Hg	0.04	0.035	**87.50**

Source: Author's Fieldwork (2013).

As shown in Figure 5.1, collectively, the highest mean of total metal concentration recorded for soil samples from the three selected e-waste sites in the Accra-Tema Metropolis was Pb (166.37 mg/kg). This was followed by Sb (44.60 mg/kg), Cu (21.70 mg/kg), Zinc (9.11 mg/kg), As (range 0.29 to 11.35 mg/kg), Cd (1.98 mg/kg) and Hg (0.48 mg/kg) in that order.

Figure 5.1: Heavy metals concentrations in soils at selected e-waste sites in the Accra-Tema Metropolis.



Source: Author's Fieldwork (2013).

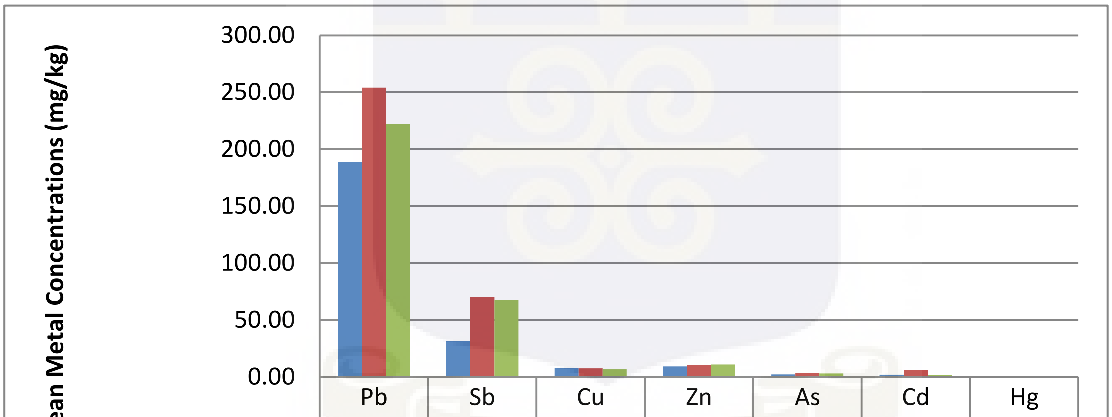
5.2.1. Heavy metals concentrations in soils from Agbogbloshie e-waste site

Mean concentrations of heavy metals in soil samples from the Agbogbloshie e-waste site were observed to be generally in the following descending order Pb (221.60 mg/kg) > Sb

(56.36 mg/kg) > Zn (10.23 mg/kg) > Cu (7.37 mg/kg) > Cd (3.19 mg/kg) > As (2.89 mg/kg) > Hg (0.37 mg/kg).

(Figure 5.2 shows the mean soil heavy metals concentrations recorded for the respective sampling stations at Agbogbloshie e-waste site). The results show that out of the seven metals analysed in this study, the open burning station (Plate 5.1) had relatively the highest mean concentrations for most of these metals, particularly, Pb (253.97 mg/kg), Sb (70.11 mg/kg), Cd (6.14 mg/kg) and As (3.39 mg/kg), whiles the Dismantling Station recorded the least concentrations for most (4 out of 7) of the metals analysed, in particular, Pb (188.53 mg/kg), Sb (31.53 mg/kg), As (2.23 mg/kg) and Zn (9.21 mg/kg) (Figure 5.2).

Figure 5.2: Heavy metals concentrations in soils at Agbogbloshie e-waste site.



	Pb	Sb	Cu	Zn	As	Cd	Hg
Dismantling Station	188.53	31.53	7.78	9.21	2.23	1.82	0.36
Open Burning Station	253.97	70.11	7.50	10.42	3.39	6.13	0.36
Disposal Station	222.31	67.43	6.84	11.05	3.05	1.62	0.40

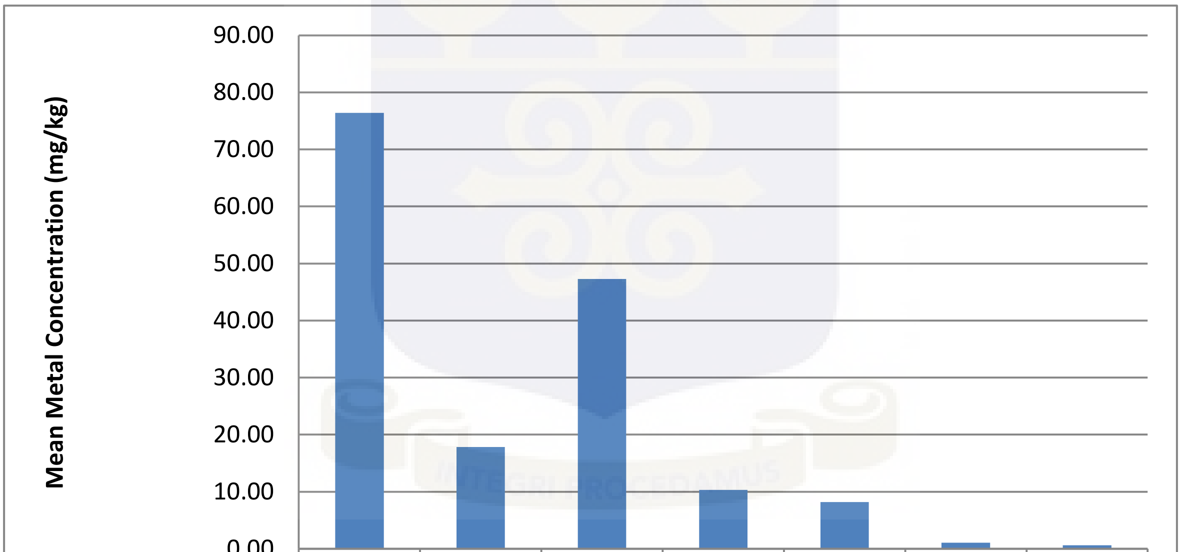
Source: Author's Field work (2013).

The Disposal Station (Plate 5.2) recorded relatively the highest mean concentration for Zn (11.05 mg/kg) and Hg (0.40 mg/kg). Notably, the same mean Hg concentration value was recorded for the open burning and dismantling stations (0.36 mg/kg). The highest soil Cu mean value (7.78 mg/kg) was recorded for the Dismantling Station, followed by the open burning station (7.50 mg/kg) and then the disposal station (6.84 mg/kg).

5.2.3. Heavy metals concentrations in soils from Tema e-waste site

Figure 5.4 shows that the highest soil metal concentration observed for the Tema e-waste site (dismantling station) was Pb (mean: 76.37 mg/kg; range: 29.39 - 138.29 mg/kg). This was followed by Cu (mean: 47.28 mg/kg; range: 14.79 - 97.40 mg/kg), Sb (mean: 17.86 mg/kg; range: 13.57 - 21.12 mg/kg), Zn (mean: 10.32 mg/kg; range: 8.49 - 14.11 mg/kg), As (mean: 8.18 mg/kg; range: 5.19 - 11.35 mg/kg), Cd (mean: 1.07 mg/kg; range: 0.93 - 1.29 mg/kg) and Hg (mean: 0.60 mg/kg; range: 0.05 - 1.44 mg/kg) in that order. As mentioned earlier in Chapter Three, neither e-waste open burning nor piling up on land, is currently being done at the Tema e-waste site, so the entire site was considered as a dismantling station.

Figure 5.4: Heavy metals concentrations in soils at Tema e-waste site.



	Pb	Sb	Cu	Zn	As	Cd	Hg
Dismantling Station	76.37	17.86	47.28	10.32	8.18	1.07	0.60

Source: Author's fieldwork (2013).

5.2.4. Heavy metals concentrations in soils from the Mataheko (Control Site)

Soil metal concentrations observed for the control site ranged from 2.60 to 172.93 mg/kg for Pb, 2.83 to 35.31 mg/kg for Sb, 2.63 to 12.28 mg/kg for Cu, 0.15 to 5.12 mg/kg for As, 0.85 to 3.75 mg/kg for Zn, 0.07 to 2.03 mg/kg for Cd, and 0.03 to 0.39 mg/kg for Hg. Figure 5.5 shows that mean metal concentrations for soil samples from the control site were in the following descending order Pb (48.14 mg/kg) > Sb (11.92 mg/kg) > Cu (6.82 mg/kg) > As (2.32 mg/kg) > Zn (2.09 mg/kg) > Cd (0.62 mg/kg) > Hg (0.14 mg/kg). Figure 5.5 shows the concentrations of heavy metals in soils from the control site.

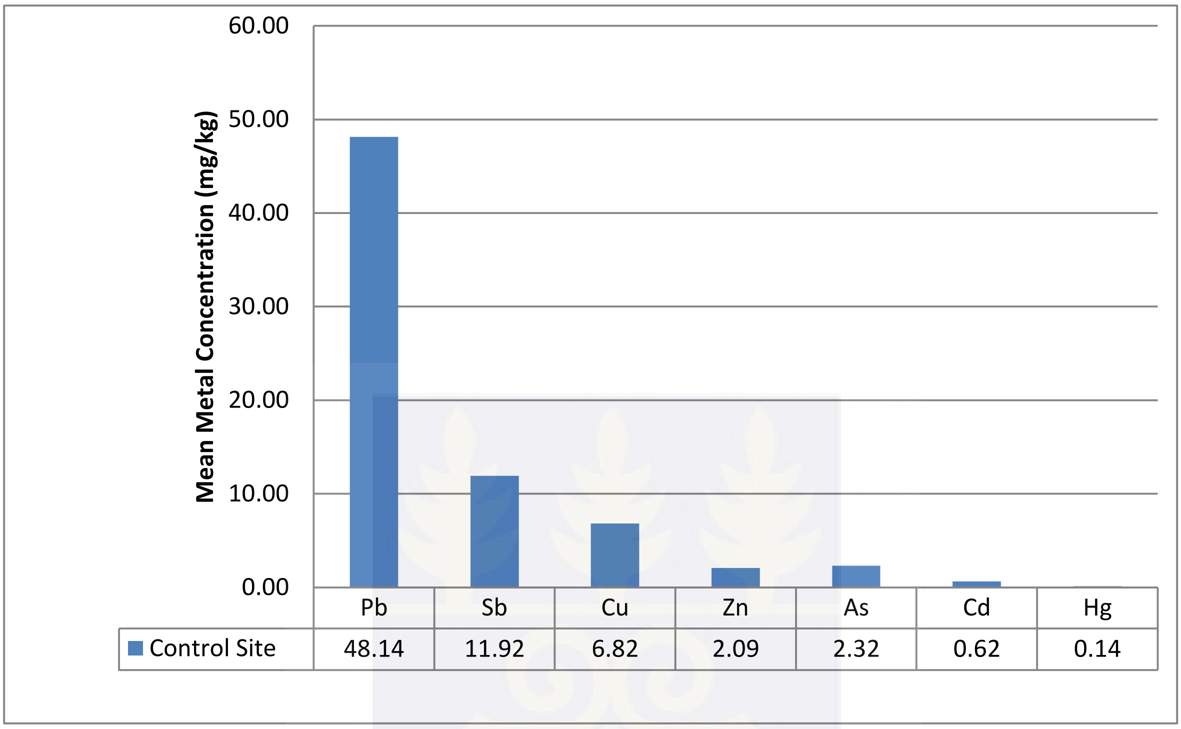


Figure 5.5: Heavy metals concentrations in soil at Control site. *Source: Authors Fieldwork (2013).*

5.2.5. Comparative analysis of heavy metals concentrations in soils from selected sites in the Accra -Tema Metropolis

A comparison of heavy metals levels in soils from the Agbogbloshie, Ashaiman and Tema e-waste sites with that of the control site, as well as the Dutch soil standard values is presented in Table 5.2. The results show that, among the e-waste dismantling stations, Agbogbloshie, followed by Ashaiman, recorded relatively higher mean soil Sb, Pb, and Cd concentrations than Tema e-waste site.

However, it was also observed that, the Tema e-waste dismantling site recorded relatively the highest mean soil Cu, Zn, and As concentrations (Table 5.2). Soil Cu and As concentrations recorded for the Ashaiman dismantling station were found to be relatively higher than that of

Agbogbloshie dismantling station. On the contrary, Agbogbloshie dismantling station recorded relatively higher mean Zn levels than Ashaiman dismantling station. For soil Hg, relatively higher mean concentration was recorded for the dismantling station at Ashaiman e-waste site than that of Tema and Agbogbloshie e-waste sites in that order (Table 5.2).

Table 5.2: Comparison of mean heavy metals concentrations in soil of sampling sites with Dutch soil standards

		----------mg/kg----------						
Location	**E-waste station**	**Pb**	**Sb**	**Cu**	**Zn**	**As**	**Cd**	**Hg**
Agbogboshie	Dismantling	188.53	31.53	7.78	9.21	2.23	1.82	0.36
Agbogboshie	Open Burning	253.97	70.11	7.50	10.42	3.39	6.14	0.36
Agbogboshie	Disposal	222.31	67.43	6.84	11.05	3.05	1.62	0.40
Agbogboshie	**Overall mean**	221.60	56.36	7.37	10.23	2.89	3.19	0.37
Ashaiman	Dismantling	155.54	27.96	34.14	7.29	6.13	1.12	0.63
Ashaiman	Open Burning	189.08	79.85	27.73	8.74	5.83	1.61	0.62
Ashaiman	Disposal	78.76	17.44	20.65	6.71	5.29	0.48	0.43
Ashaiman	**Overall mean**	141.13	41.75	27.51	7.58	5.75	1.07	0.56
Tema	Dismantling	76.37	17.86	47.28	10.32	8.18	1.07	0.60
Mataheko (control)		**48.14**	**11.92**	**6.82**	**2.09**	**2.32**	**0.62**	**0.14**
Dutch target value		**85.00**	**3.00**	**36.00**	**140.0**	**29.00**	**0.80**	**0.30**
Dutch intervention value		**530.0**	**15.00**	**190.0**	**720.0**	**55.00**	**12.00**	**10.00**

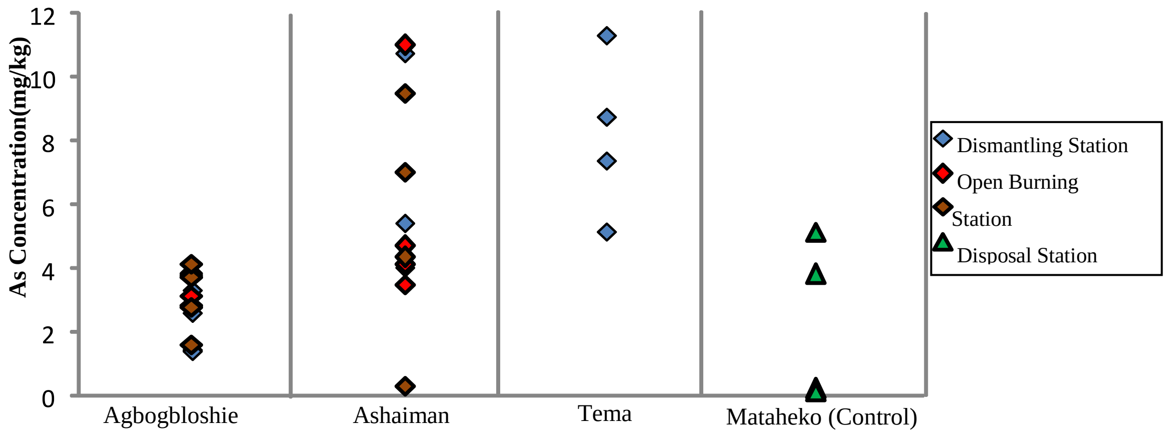
Source: Author's Fieldwork (2013)

Statistically, no significant differences were observed for heavy metals concentrations in soil among the three dismantling stations except for Pb and As levels between the Tema and Agbogbloshie e-waste Dismantling Stations. Common e-waste dismantling activity observed during the field visit at the respective e-waste sites is the use of chisels and hammers by e-waste workers to dismantle e-waste, like CRT monitors so as to recover copper and other valuable materials. E-waste dismantling activities can release dust particles containing heavy metals and flame retardants into the atmosphere. These particles either re-deposit (wet or dry deposition) near the emission source or can be transported over long distances depending on their sizes (Sepúlveda, 2010).

Comparing heavy metals levels between the e-waste Open Burning Stations, it was noticed that out of the seven metals analysed in this study, the Ashaiman Open Burning Station recorded relatively higher concentrations for most of the metals (i.e. As (Figure 5.6), Cu, Sb, As and Hg) than the Agbogbloshie Open Burning Station (Table 5.2). On the other hand, soil Cd (Figure 5.7), Pb and Zn concentrations observed for the Agbogbloshie Open Burning Station were relatively higher than those of Ashaiman Open Burning Station (Table 5.2). Statistically, all the determined heavy metals (Pb, Sb, Cu, Zn, As, Cd and Hg) concentrations between the Agbogbloshie and Ashaiman Open Burning Stations showed no significant differences.

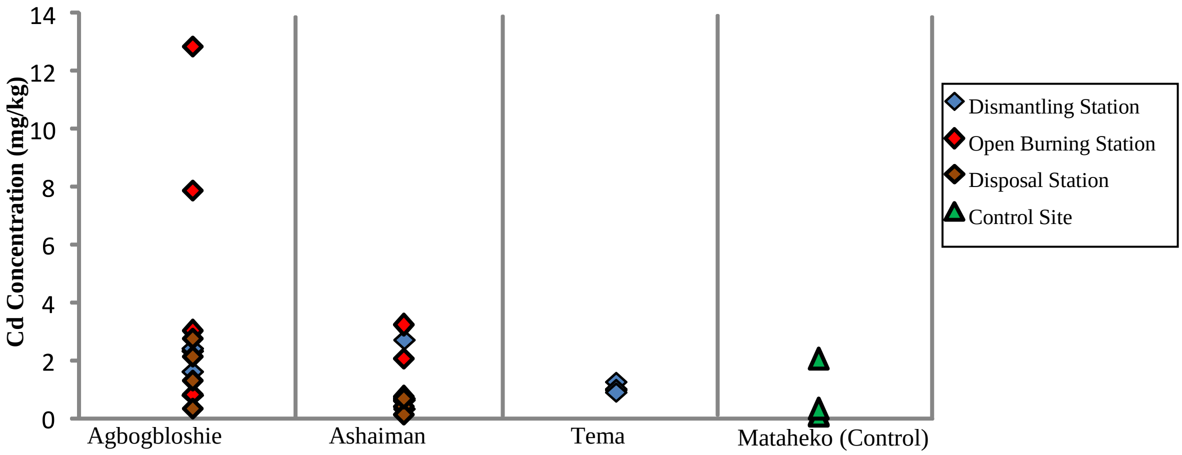
The environmental fate of particles, ashes and fumes containing heavy metals and other e-waste hazardous substances released by burning activities is similar to that of the emissions released by dismantling activities (Sepúlveda *et al.*, 2010). Open burning of e-waste leads to the release of copper, lead, zinc, cadmium and other hazardous substances from e-waste into soil, air and water, and pose a risk to ecosystems and human health (Wilmoth *et al.*, 1991; Ayodeji, 2011).

Figure 5.6. Comparison of As concentrations in soils from sampling sites.



Source: Author's Fieldwork (2013).

Figure 5.7: Comparison of Cd concentrations in soils from sampling sites.



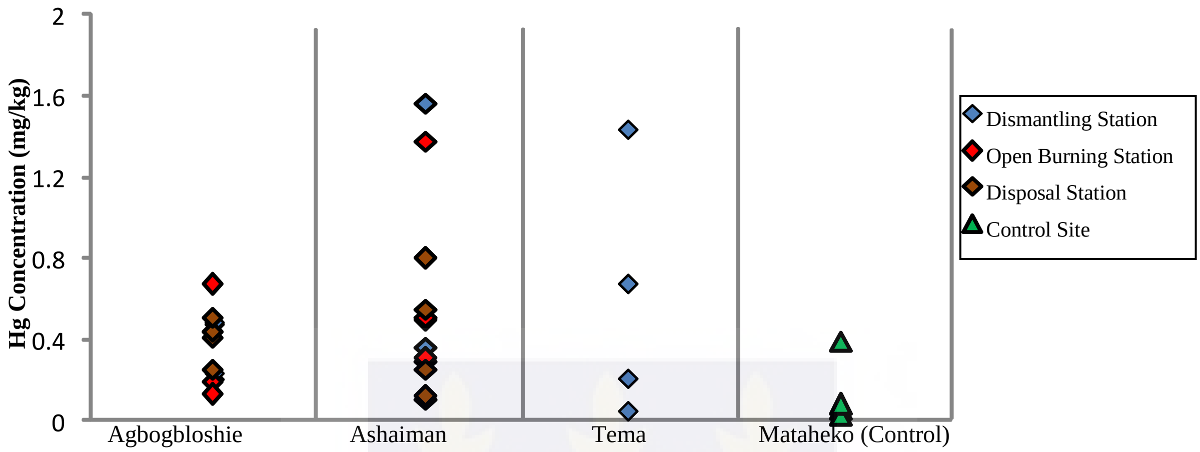
Source: Author's Fieldwork (2013).

Regarding heavy metal concentrations in soil from the e-waste disposal stations, it can be noticed in Table 5.2 that the Agbogbloshie Disposal Station had relatively higher mean concentrations for most of the metals analysed (i.e. Pb, Sb, Zn and Cd) than the Ashaiman Disposal Station. This is not so surprising because during the field visit huge piles of non-recycle e-waste parts including plastic casing of TV and computer monitors were found at the Agbogbloshie dumpsite compared to Ashaiman dumpsite site. However, As (Figure 5.6), Hg (Figure 5.8) and Cu concentrations recorded for soil samples from the Agbogbloshie Disposal Station were found to be relatively lower than that of Ashaiman e-waste Disposal station (Table 5.2). Statistically, the only significant differences with regard to soil metals concentrations between the Agbogbloshie and Ashaiman disposal stations were observed for Pb and Sb.

Remarkably, it was observed that all the three sampling stations (Dismantling, Open Burning and Disposal) at the Agbogbloshie e-waste site recorded relatively higher mean soil Pb, Zn and Cd levels than the corresponding sampling stations at Ashaiman e-waste site. Similarly, all the three e-waste sampling stations (Dismantling, Open Burning and Disposal) at the

Ashaiman e-waste site had relatively higher mean soil Cu, As and Hg concentrations than the corresponding stations at Agbogbloshie e-waste site (Table 5.2).

Figure 5.8: Comparison of Hg concentrations in soils from sampling sites.



Source: Author's Fieldwork (2013).

Comparing the concentrations of metals in soil from the e-waste sites with the control site, the results show that, except for As and Cd mean levels recorded respectively for Agbogbloshie dismantling station and Ashaiman disposal station, soil Pb, Sb, Cu, Zn, Hg As, and Cd, mean concentrations observed for the stations at Agbogbloshie, Ashaiman and Tema e-waste sites were high compared with the control site (Table 5.2). This indicates that the primitive ways of e-waste dismantling at the e-waste sites, and open burning and disposal activities at the Agbogbloshie and Ashaiman e-waste sites could have resulted in the release of these heavy metals in soil at the selected e-waste sites in the Accra - Tema Metropolis, which can lead to potential environmental and human health risks.

Statistically, it was noticed that except for Ashaiman, Zn levels recorded for the Tema e-waste (dismantling) site as well as the three sampling stations (dismantling, open burning and disposal stations) at the Agbogbloshie e-waste site were significantly higher compared with that of the control site. Similarly, Pb levels recorded for the open burning station at the Ashaiman e-waste site and the three sampling stations (dismantling, open burning and disposal stations) at the Agbogbloshie e-waste site were significantly higher than that of the control site.

Furthermore, soil As level recorded for the the Tema e-waste (dismantling) site, and Sb and Hg levels recorded for Agbogbloshie e-waste disposal station were observed to be significantly high compared with those of the control site. Apart from these, no other significant differences were observed in heavy metals levels between the control group and the e-waste sites in this study. The significant levels of heavy metals observed in soil at the respective e-waste sites compared with the control site suggest release from e-waste processing activities at the respective e-waste sites in this study. Thus, the hypothesis of this study, that crude e-waste recycling practices lead to significant heavy metals contamination of soil at e-waste sites is true for Pb, Zn, As, Sb and Hg in the case of the Accra-Tema Metropolis.

Heavy metals released in soils remain even after their addition to soils has been stopped due to their persistence and non-degradability nature (Hesterberg, 1998, Gutiérrez-Ginés *et al.*, 2010, Ezeh and Chukwu, 2012 in Matthews-Amune *et al.*, 2012). The elevated metal concentrations observed at Ashaiman (Pb), Tema (As and Zn) and Agbogbloshie (Pb, Zn, Sb and Hg) e-waste sites compared with the control site is therefore of concern as they can cause adverse effects on soil, such as reduction of soil microbial biomass levels which are responsible for maintenance of soil fertility for optimum crop yield (Hesterberg, 1998, Jung, 2008 in Matthews-Amune *et al.*, 2012).

Furthermore, the high metal concentrations in soil at these e-waste sites could potentially contaminate nearby water bodies through leaching or water runoff, and may further contaminate adjourning agricultural fields. This is particularly so for the Agbogbloshie site which is situated on the bank of the Odaw river, and in the upper reaches of the Korle Lagoon in Accra. The mobility of these metals towards other environmental compartments depends on diverse environmental parameters like pH, organic matter content, temperature, adsorption–desorption processes, complexation, uptake by biota, degradation processes, and the intrinsic chemical characteristics of the substance (Sauvé *et al*., 2000; Georgopoulos *et al*., 2001; Hu, 2002; Gouin and Harner, 2003; Qin et al., 2004 in Sepúlveda et al., 2010).

It is worth mentioning that both Agbogbloshie and Tema e-waste sites are located within open air food market area. This is of concern because food items like vegetables, placed on top of polyethylene sacs or in plastic buckets on the ground could easily come into contact with contaminated dust especially during the dry season (Leung *et al*., 2008 in Sepúlveda *et al*., 2009), and might consequently affect the health of consumers. Also, of concern are animals, particularly goats and cattle noticed grazing around the e-waste sites at Agbogbloshie and Ashaiman.

As mentioned earlier, the soil heavy metals concentrations were also compared to the Dutch soil quality standard values. The Dutch Standards are environmental pollutant reference values (i.e., concentrations in environmental medium) used in environmental remediation, investigation and clean-up. Excluding a few exceptions, the target values are underpinned by an environmental risk analysis wherever possible and apply to individual substances. In most cases, target values for the various substances are related to a national background concentration that was determined for the Netherlands (http://www.wikipedia.com).

All the mean heavy metal concentrations recorded for the control site were found to be relatively lower than the Dutch target and intervention values for soil metal. This indicates non-contamination of soil by heavy metals at the Mataheko control site. However, for the e-waste sites, it was observed that, except for Zn, Cu and As levels, overall mean Pb, Sb, Cd and Hg concentrations recorded for the Agbogbloshie and Ashaiman e-waste sites exceeded the Dutch target values for these metals (Table 5.2). This implies that e-waste processing activities at the Agbogbloshie and Ashaiman e-waste sites have contributed to Pb, Sb, Cd and Hg contamination of soil at these sites. Similarly, it was noticed that except for Pb, Zn, As levels, mean Sb, Cu, Cd and Hg concentrations observed for the Tema e-waste site (dismantling station) were more compared to the Dutch target values for these metals (Table 5.2). This also indicates Sb, Cu, Cd and Hg contamination of soil from e-waste dismantling activities at the Tema e-waste site.

The Dutch soil remediation intervention values indicate when the functional properties of the soil for humans, plants and animals are seriously impaired or threatened. They are representative of the level of contamination above which a serious case of soil contamination is deemed to exist. The Dutch intervention value for soil Sb is 15 mg/kg dry weight. Notably, none of the e-waste sites recorded higher mean heavy metal concentrations than the Dutch intervention values except for Sb levels observed for the all the three e-waste sites (Table 5.2). Even though antimony is a naturally occurring metal, concentrations in soil are commonly rather low (Brigden *et al*., 2008). This indicates that e-waste activities may have contributed to serious Sb contamination of soil at Agbogbloshie, Ashaiman and Tema e-waste sites and poses a serious threat to human, plants and animals.

Even though this study did not determine the sources of these metals with regard to the specific components they were released from, they all have various known uses in electrical and electronic equipment and could be released into the environment through primitive e-waste recycling practices like open burning and disposal on land. For instance, lead is widely used in electrical and electronic products, ranging from printed circuit boards, batteries to cathode ray tubes and as stabilizers in PVC cables, and is mainly recovered by manually de-soldering the components of e.g. printed circuit boards (Wang *et al*., 2011). Mercury is one of the most toxic metals, yet widely used in lighting device that illuminate flat screen displays. Some older computer may contain batteries containing mercury (OECD, 2003; Swedish Environmental Protection Agency, 2011). Antimony is also used in the manufacture of lead acid starter batteries (Kentner *et al*., 1995 as cited by Brigden *et al*., 2008), and can occur as a component of electrical solders as well as in CRT glass (Swedish Environmental Protection Agency, 2011). Copper is a key component in electric wires and cables and is primarily recovered by open burning (Wang *et al*., 2011).

Cadmium was used in electronics in some switches and solder joints, and as cadmium compounds in rechargeable batteries, UV stabilizers in older PVC cables and ‘‘phosphor’’ coatings in older cathode ray tubes (Zheng *et al*., 2008). Zinc, found in the form of Zinc sulphide is used in luminescent pigments on the interior of CRT screens (Swedish Environmental Protection Agency, 2011). Arsenic is mainly found in the form gallium arsenide in electrical and electronic equipment, and used in devices such as microwave frequency integrated circuits, infrared light emitting diodes (LEDs), laser diodes and solar cells (Flora, 2000; Uryu *et al*., 2003 as cited by Swedish Environmental Protection Agency, 2011).The findings of this study thus confirm that the current management practices by way of crude dismantling, open burning and disposal of e-waste have contributed to heavy metals contamination of soil at e-waste sites in the Accra- Tema Metropolis, which could have adverse implications for the environment and human health.

Comparing the soil metals concentrations in this study with previous studies in Ghana, it was observed that Hg and As levels observed for the Agbogbloshie (range: Hg: 0.13 - 0.67 mg/kg; As 1.44- 4.12 mg/kg), Ashaiman (range: Hg: 0.11 - 1.56 mg/kg; As: 0.29 - 11.00 mg/kg) and Tema (range: Hg: 0.05 - 1.44 mg/kg; As: 5.19 -11.35 mg/kg) e-waste sites were lower than the range of previous study by Asante *et al*. (2011) (range: Hg: <20 - 50 mg/kg; As:<50 -

1100 mg/kg), but higher than the study by Brigden et al. (2008) in Agbogbloshie (Hg: <0.5; As: <20 mg/kg). Also, mean Hg levels recorded for Agbogbloshie (0.36 to 0.40 mg/kg), Ashaiman (0.43 to 0.63 mg/kg) and Tema (0.60 mg/kg) e-waste sites were found to be higher than the minimum mean value (0.11 mg/kg) and lower than and maximum mean value (1.3 mg/kg) recorded by Amfo-Otu et al. (2013) in Tema.

Furthermore, soil Zn concentrations recorded for the three respective e-waste sites in this study were found to be far lower compared with the study results by Asante *et al*. (2011) (soil/ash mixture: 200 - 160000 mg/kg) and Brigden *et al*. (2008) (soil: 274 mg; soil/ash mixture: 6920 - 31300 mg/kg). Again, almost all the soil samples had very low Cu levels compared with the study results by Brigden *et al.* (2008) in Agbogbloshie (soil:85 mg/kg; soil/ash mixture range: 119 - 9730 mg/kg), and Amfo-Otu *et al*. (2013) in Tema (mean: 7834.92 - 1688.11 mg/kg).

It was also observed that whereas soil Cd levels recorded for the Tema (range: 1.29 - 0.93 mg/kg) and Ashaiman (range: 0.14 - 3.20 mg/kg) e-waste sites were lower than the range of the study by Brigden *et al*. (2008) (<1 - 10 mg/kg) and Amfo-Otu *et al* (2013) (mean: 1.4 - 2.6 mg/kg), that recorded for the Agbogbloshie e-waste site (range: 0.33 - 12.88; mean: 1.62 - 6.14 mg/kg) was found to be higher compared with the previous studies by Brigden *et al*. (2008) and Amfo-Otu *et al*. (2013).

Furthermore, with the exception of the minimum Sb level recorded for the disposal Station at Ashaiman e-waste site (2.57 mg/kg, Appendix E1), Sb concentrations observed for all soil samples from the three e-waste sites in this study were high compared with similar soil studies from Agbogbloshie e-waste disposal area (8 mg/kg by Brigden *et al*., 2008), but lower than range of previous results for soil/ash mixture from the Agbogbloshie e-waste open burning areas (16 - 592 mg/kg) (Brigden *et al*., 2008). Pb levels recorded for soil samples from Agbogbloshie (range: 143.72 - 265.03), Ashaiman (range: 3.45 – 262.2 mg/kg) and Tema (29.39 – 138.3 mg/kg) e-waste sites fell below the range of previous studies by Brigden *et al.* (2008) (110 - 5510 mg/kg), Asante *et al*. (2012) (100 - 14000 mg/kg) and Caravanos *et al.* (2011) (134 - 18,125 mg/kg) in Agbogbloshie. The relatively lower Cu, Cd and Hg levels observed for the control site (Table 5.2) than those recorded for the all the three e-waste sites in this study compares favourably with the study results by Amfo-Otu *et al*. (2013) in Tema.

5.3. Heavy Metals Concentrations in urine

Urinary metal concentrations in samples obtained from e-waste workers in the Accra-Tema Metropolis and the control group are shown in Tables 5.2 to 5.5. The results showed that urinary metal levels ranged from <0.003- 1.048 mg/ L for copper (Cu), <0.001 - 0.216 for zinc (Zn), <0.040 - 2.072 mg/L for antimony (Sb), <0.001 - 0.404 mg/L for lead (Pb), <0.001 - 0.068 mg/L for arsenic (As), <0.002 - 0.08 mg/L for cadmium, and <0.001 mg/L for mercury (Hg). Generally, Sb was high in all the urine samples. On the contrary, Hg (<0.001 mg/L) was not detected in any of the urine samples.

5.3.1. Levels of heavy metals in urine of Agbogbloshie e-waste workers

Levels of metals in urine samples of Agbogbloshie e-waste workers (AGB-EWW) are shown in Table 5.3. The results show that Sb (range: 0.056 mg/L to 1.804mg/L; mean: 0.836 mg/L) was the highest in urine samples from Agbogbloshie e-waste workers. This was followed by Cu (range: 0.748 to 1.048 mg/L; mean: 0.827 mg/L), Pb (range: 0.108 mg/L - 0.404 mg/L; mean 0.323 mg/L) and Zn (range: 0.124 - 0.216; mean: 0.163 mg/L) and As (range: <0.001 to 0.008 mg/L; mean: 0.006 mg/L) in that order. Remarkably, all the e-waste workers had urinary Cd (<0.002 mg/L) and Hg (<0.001mg/L) below the detection limits. Furthermore, one of the subjects had urinary As concentration below the detection limit (<0.001 mg/kg) whiles majority (5) recorded the same urinary As level of 0.008 mg/L (Table 5.3). As shown in Table 5.3, two of the Agbogbloshie e-waste workers recorded the same Zn concentration of 0.16 mg/L.

Table 5.3: Concentrations of heavy metals in urine of Agbogbloshie e-waste workers

	mg/L						
Subject Code	**Cu**	**Sb**	**Zn**	**Pb**	**As**	**Cd**	**Hg**
AGB-EWW1	0.748	1.804	0.128	0.108	Nd	Nd	Nd
AGB-EWW2	0.832	1.456	0.16	0.336	0.008	Nd	Nd
AGB-EWW3	1.048	0.472	0.16	0.364	0.008	Nd	Nd
AGB-EWW4	0.8	0.892	0.216	0.336	0.004	Nd	Nd
AGB-EWW5	0.748	0.364	0.184	0.368	0.008	Nd	Nd
AGB-EWW6	0.868	1.204	0.192	0.288	0.004	Nd	Nd
AGB-EWW7	0.772	0.056	0.14	0.404	0.008	Nd	Nd
AGB-EWW8	0.796	0.44	0.124	0.376	0.008	Nd	Nd

Source: Author's Fieldwork (2013).
Nd means not detected.

Urinary metal concentrations recorded for the Agbogbloshie e-waste workers varied from 0.748 to 1.048 for Cu, 0.108 mg/L to 0.404 mg/L for Pb, 0.056 mg/L to 1.804mg/L for Sb, <0.001 to 0.008 mg/L for As. None of the e-waste workers had Cd (<0.002 mg/L), and Hg (<0.001mg/l) detected in their urine samples. Appendix E2 shows that all the Agbogbloshie e-waste participants aged between 12 and 24 had urinary Sb levels exceeding that of the Germany reference value (0.3 µg/l = 0.0003 mg/L) for Sb in urine of children.

5.3.2. Levels of heavy metals in urine of Ashaiman e-waste workers

The concentrations of heavy metals in urine of Ashaiman e-waste workers (ASH-EWW) are listed in Table 54.

Table 5.4: Concentrations of heavy metals in urine of Ashaiman e-waste workers

	-----------------------------------mg/L-----------------------------------						
Subject Code	**Cu**	**Sb**	**Zn**	**Pb**	**As**	**Cd**	**Hg**
ASH-EWW1	Nd	0.524	Nd	0.016	0.012	Nd	Nd
ASH-EWW2	Nd	0.478	Nd	0.028	0.02	Nd	Nd
ASH-EWW3	Nd	0.372	Nd	0.056	0.024	Nd	Nd
ASH-EWW4	Nd	0.448	Nd	0.024	0.068	Nd	Nd
ASH-EWW5	Nd	0.384	Nd	0.016	0.052	Nd	Nd
ASH-EWW6	Nd	0.428	Nd	0.044	0.024	Nd	Nd
ASH-EWW7	Nd	0.098	Nd	0.012	Nd	Nd	Nd
ASH-EWW8	Nd	0.368	Nd	0.014	0.02	Nd	Nd

Source: Author's Fieldwork (2013).
Nd means not detected.

It can be noticed from Table 5.4 that of the seven metals determined, only three (Sb, Pb, and As) were detected in the urine samples. The highest urinary metal level was observed for Sb, and ranged from 0.098 to 0.524 mg/L with a mean concentration of (0.163 mg/L). Next was As (range <0.001 - 0.068 mg/L; mean: 0.012 mg/L) and then Pb (range: 0.012 - 0.056 mg/L; mean: 0.005 mg/L). All the eight e-waste workers from Ashaiman had urinary Cu (<0.003), Zn (<0.001mg/l), Cd (<0.002 mg/l) and Hg (<0.001 mg/l) below the detection limits (Table 5.4). Also, one of the eight workers had urinary As concentration below detection limits (<0.001 mg/L).

5.3.3. Levels of heavy metals in urine of Tema e-waste workers

As shown in Table 5.5, most of the metals analysed in the urine samples from the Tema e-waste workers (TMA-EWW) were below detection limits. None of the e-waste workers had Cu, Zn, Cd and Hg detected in their urine samples. Urinary As was also below detection limit for one of the e-waste workers. Furthermore, only three of the eight e-waste workers had Pb detected in their urine. Of the three urinary metals detected, Sb recorded the highest concentration, ranging from 0.040 to 0.304 mg/L with a mean value of (0.163 mg/L). This was followed by As (range: <0.001 - 0.020 mg/L) and then Pb (range: <0.001 - 0.016 mg/L).

Table 5.5: Concentrations of heavy metals in urine of Tema e-waste workers

	mg/L						
Subject Code	**Cu**	**Sb**	**Zn**	**Pb**	**As**	**Cd**	**Hg**
TMA-EWW1	Nd	0.264	Nd	Nd	0.008	Nd	Nd
TMA-EWW2	Nd	0.180	Nd	Nd	0.012	Nd	Nd
TMA-EWW3	Nd	0.080	Nd	0.012	0.020	Nd	Nd
TMA-EWW4	Nd	0.304	Nd	Nd	0.020	Nd	Nd
TMA-EWW5	Nd	0.244	Nd	Nd	0.012	Nd	Nd
TMA-EWW6	Nd	0.068	Nd	Nd	0.008	Nd	Nd
TMA-EWW7	Nd	0.040	Nd	0.016	0.016	Nd	Nd
TMA-EWW8	Nd	0.120	Nd	0.012	Nd	Nd	Nd

Source: Author's Feldwork (2013).

Nd means not detected.

5.3.4. Levels of heavy metals in urine of Mataheko Control Group

The results show that the highest metal concentration in urine of the control group (MAT-CTR) was recorded for Sb (<0.040 - 2.072 mg/L), followed by Cu (<0.003 - 0.81 mg/L), Pb (<0.001 - 0.32 mg/L), Zn (<0.001 - 0.116 mg/L, Cd (<0.002 - 0.08 mg/L) and then As (<0.001 - 0.01 mg/L) (Table 5.9). All the subjects had urinary mercury below detection limits (<0.001 mg/L). It was noticed that majority (7) of the control samples recorded urinary Cd below detection limits (<0.002 mg/L). The only urinary Cd (0.08 mg/L) concentration recorded was observed for a 13 year old female child. Six of the subjects had urinary As level below detection limit (<0.001 mg/L). Furthermore, three (37.5%) out of the eight subjects neither had Cu (<0.003mg/L), Zn (<0.001 mg/L), and Pb (<0.001 mg/L) below the detection limits, and, one of the subjects recorded urinary Sb below the detection limit (<0.001 mg/L) (Table 5.6).

Table 5.6: Concentrations of heavy metals in urine of Mataheko Control Group

	--------------------------------------mg/L------------------------------------						
Subject Code	**Cu**	**Sb**	**Zn**	**Pb**	**As**	**Cd**	**Hg**
MAT-CTR1	0.81	1.01	0.116	0.32	Nd	Nd	Nd
MAT-CTR2	0.764	0.86	0.096	0.276	Nd	Nd	Nd
MAT-CTR3	Nd	1.54	Nd	Nd	Nd	Nd	Nd
MAT-CTR4	Nd	2.072	Nd	Nd	Nd	0.08	Nd
MAT-CTR5	Nd	1.956	Nd	Nd	Nd	Nd	Nd
MAT-CTR6	0.628	0.177	0.033	0.011	Nd	Nd	Nd
MAT-CTR7	0.662	0.194	0.048	0.03	0.01	Nd	Nd
MAT-CTR8	0.284	Nd	0.016	0.012	0.008	Nd	Nd

Source: Author's Feldwork (2013).
Nd means not detected.

5.3.5. Comparative Analysis of Heavy Metals Concentrations in Urine

A comparison of heavy metals concentrations in urine of e-waste workers and the control group are presented in Table 5.7 and Figures 5.14 to 5.19. The results show that, among the e-waste working groups, the Agogbloshie e-waste workers relatively recorded the highest mean concentrations for most (4 out 5) of the metals detected in urine samples, particularly Cu (0.827 mg/L), Zn (0.163 mg/L), Sb (0.836 mg/L), and Pb (0.323 mg/L) (Table 5.7). This was followed by the Ashaiman e-waste workers (Sb = 0.388; Pb = 0.026) and then Tema e-waste workers (Sb = 0.163; Pb = 0.005) (Table 5.7). This suggests that e-waste workers at the Agbogbloshie e-waste site may be more exposed to heavy metals in the environment than e-waste workers at Ashaiman and Tema e-waste sites.

This observed trend is not so surprising because, Agbogbloshie is noted to be the main centre of e-waste recycling activities in Ghana (Brigden *et al*., 2008), and thus its environment is likely to contain more pollutants than the two other e-waste sites. It is also important to reiterate that, unlike the Agbogbloshie and Ashaiman e-waste sites, the open burning of e-waste which the soil results of this study has shown to be the leading activity that leads to the release of relatively more concentrations of heavy metals into the environment, is currently not being conducted at the Tema e-waste site. Only dismantling of e-waste is presently being carried out at the Tema e-waste site. Hence, the level of heavy metal exposure to workers at the Tema e-waste site could be expected to be relatively low.

Table 5.7: Comparison of heavy metals concentrations in urine of control group and e-waste workers from selected sites in the Accra-Tema Metropolis

		---mg/L---						
Group code		Cu	Zn	Sb	Pb	As	Cd	Hg
AGB-EWW	n	*8/8*	*8/8*	*8/8*	*8/8*	*7/8*	0/8	0/8
	Mean	0.827	0.163	0.836	0.323	0.006	<0.002	<0.001
	SD	0.098	0.032	0.607	0.093	0.003		
	Min	0.748	0.124	0.056	0.108	<0.001	<0.002	<0.001
	Max	1.048	0.216	1.804	0.404	0.008	<0.002	<0.001
ASH-EWW	n	0/8	0/8	*8/8*	*8/8*	*7/8*	0/8	0/8
	Mean	<0.003	<0.001	0.388	0.026	0.028	<0.002	<0.001
	SD			0.129	0.016	0.022		
	Min	<0.003	<0.001	0.098	0.012	<0.001	<0.002	<0.001
	Max	<0.003	<0.001	0.524	0.056	0.068	<0.002	<0.001
TMA-EWW	n	0/8	0/8	*8/8*	*3/8*	*7/8*	0/8	0/8
	Mean	<0.003	<0.001	0.163	0.005	0.012	<0.002	<0.001
	SD			0.100	0.007	0.007		
	Min	<0.003	<0.001	0.04	<0.001	<0.001	<0.002	<0.001
	Max	<0.003	<0.001	0.304	0.016	0.02	<0.002	<0.001
MAT-CTR	n	*5/8*	*5/8*	*7/8*	*5/8*	*2/8*	*1/8*	0/8
	Mean	0.394	0.039	0.979	0.081	0.003		<0.001
	SD	0.361	0.045	0.816	0.135	0.004		
	Min	<0.003	<0.001	<0.040	<0.001	<0.001	<0.002	<0.001
	Max	0.81	0.116	2.072	0.32	0.01	0.08	<0.001

Source: Author's Fieldwork (2013).

Again, whereas all the Agbogbloshie e-waste participants involved in this study, do engage in open burning activities, only 4 (50%) and 3 (37.5%) of the Ashaiman and Tema e-waste participants, respectively engage in such activity alongside e-waste collection or dismantling. This further suggests that the open burning of e-waste could have also influenced the generally high urinary heavy metals levels observed for the e-waste participants at the Agbogbloshie e-waste site than those at the Ashaiman ante Tema e-waste sites in that order.

Notably, none of the Ashaiman and Tema e-waste workers had Cu and Zn detected in their urine samples. However, all the Agbogbloshie e-waste subjects had Zn detected in their urine samples, ranging from 0.124 to 0.216 mg/L (Table 5.7).

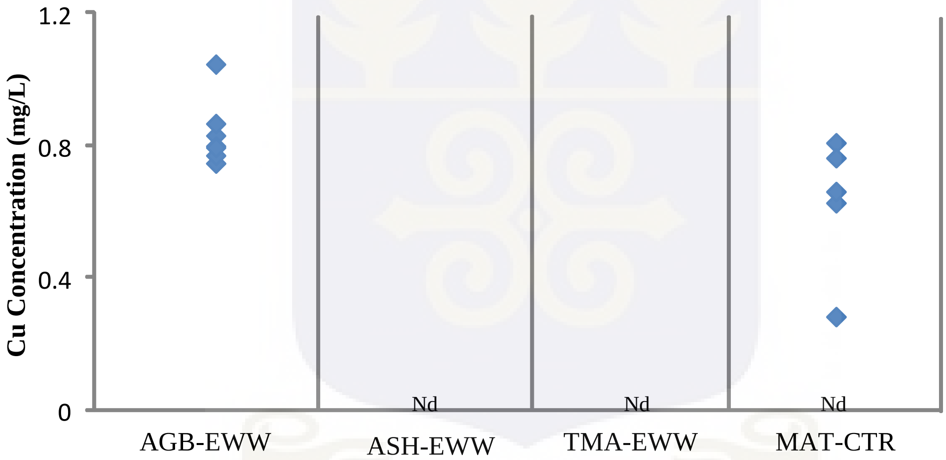
Statistically, except for Sb, urinary Cu, Zn, and Pb concentrations recorded for the Agbogbloshie e-waste workers were found to be significantly ($p < 0.05$) higher compared with those for the Ashaiman and Tema e-waste workers. Thus, suggesting relatively higher level of exposure of e-waste workers to these metals at the Agbogbloshie e-waste site. Though not statistically significant, the relatively high mean Sb levels in urine of Agbogbloshie e-waste workers than the Ashaiman and Tema e-waste workers could have been contributed by other sources (which may include diet) other than e-waste recycling activity exposure.

No significant differences ($p > 0.05$) were observed with regard to urinary Cu, Zn, Sb and Pb concentrations between Ashaiman and Tema e-waste workers. However, the high mean urinary Pb and Sb levels recorded for Ashaiman e-waste workers compared with the Tema e-waste workers may also suggest human exposure risk to these metals at Ashaiman e-waste site than the Tema e-waste site. This was not so surprising because as indicated earlier in chapter four, this study showed that soil samples from the Agbogbloshie e-waste site, followed by the Ashaiman e-waste site recorded relatively high mean soil Pb and Sb concentrations values than the Tema e-waste site.

With respect to arsenic levels in urine, the Ashaiman e-waste workers (0.028 mg/L) had relatively the highest mean concentration value (Table 5.9). This was followed by the Tema e-waste workers (0.012 mg/L) and then the Agbogbloshie e-waste workers (0.006 mg/L) (Table 5.9). The only significant difference observed in As levels was between the Ashaiman and Agbogbloshie e-waste workers.

As mentioned earlier, urinary Cd and Hg levels were below detection limits for all the e-waste workers involved in this study, suggesting no or low exposure to these metals at the respective e-waste sites (Table 5.9). Previous studies by Asante *et al*. (2012) and Caravanos *et al*. (2013) in Agbogbloshie did not detect Hg in urine of e-waste workers but reported mean Cd concentration values of 0.43ug (Asante *et al*., 2012) and 0.013 ppm (Caravanos *et al*., 2013) for urine samples from e-waste exposed group. It is worth mentioning that the results for the heavy the metals concentrations in soil also showed that among the seven metals analysed, mean Cd and Hg concentrations in soil at the respective e-waste sites were relatively the lowest.

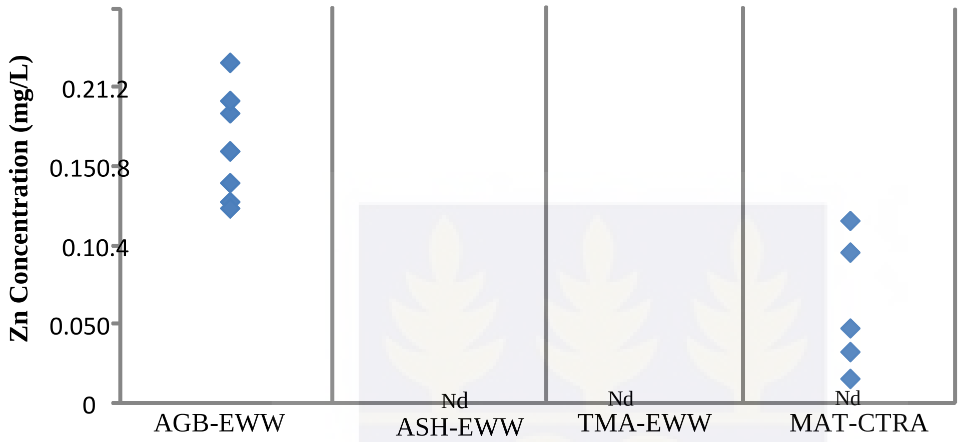
Figure 5.9: Comparison of Cu concentrations in urine of e-waste workers with control group.



Source: Author's Feldwork (2013).
Nd means not detected.

Comparing heavy metals concentrations in urine of e-waste workers with those of the control group, it was observed that urinary Cu (mean: 0.827 mg/L) and Zn (mean: 0.163 mg/L) levels recorded for the Agbogbloshie e-waste workers were significantly high compared with those of the control group (mean :Cu = 0.394 mg/L; Zn = 0.039 mg/L). On contrary, urinary Cu (<0.003 mg/L) and Zn (<0.001 mg/L) levels observed for both Ashaiman and Tema e-waste workers were below detection limits (see Figures 5.9 and 5.10), and were hence, significantly lower compared with those of the control group. Cu and Zn are essential trace elements that can cause symptoms of deficiency and can be toxic when exposures exceed physiological needs. Human exposure to these elements includes the inhalation of fumes or the particulates of these elements, ingestion of food, water or dust, and dermal contact with contaminated soil or water (WHO, 2003).

Figure 5.10: Comparison of Zn concentrations in urine of e-waste workers with control group.



Source: Author's Feldwork (2013).
Nd means not detected.

The non-detection of Cu and Zn in urine of Ashaiman and Tema e-waste participants suggests that crude e-waste processing activities at the Ashaiman and Tema e-waste sites might not have influenced Cu and Zn exposure levels in e-waste workers at these e-waste sites. The elevated Cu and Zn levels in urine of the Agbogbloshie e-waste workers could be attributed to exposure from environmental contamination related to crude e-waste recycling practices at the Agbogbloshie e-waste site. Exposure to higher doses of copper can cause adverse health effects, including gastrointestinal distress (nausea, vomiting, abdominal pain), respiratory tract irritation, liver and kidney damage, anaemia, immuno toxicity, and developmental toxicity (Swedish Environmental Protection Agency, 2011) and can even cause death under extremely high ingestion (CDPHE, 2008; Amfo-Otu *et al*., 2013).

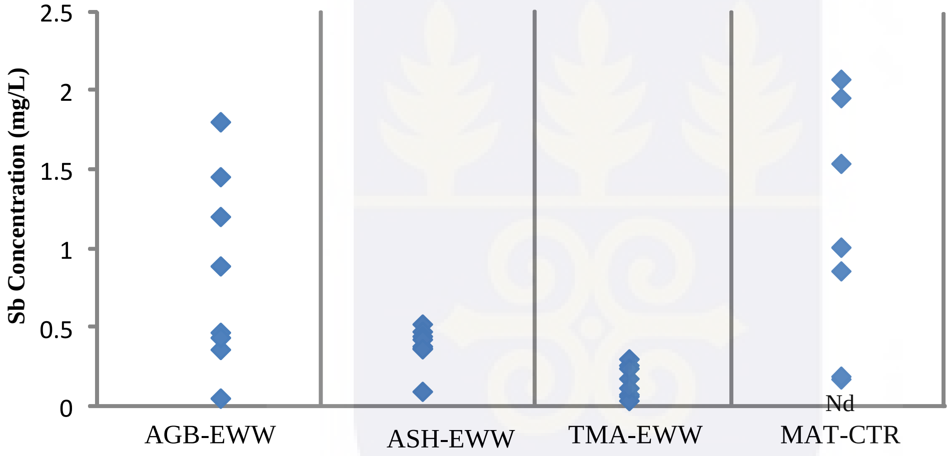
Occupational exposure to high levels of zinc oxide and/or nonferrous metals is associated with metal-fume fever, which is usually a short-term, self-limiting syndrome, characterized by a variety of symptoms including fever, chills, dyspnoea, nausea and fatigue. The condition is generally severe but transient, and individuals tend to develop tolerance (WHO, 2003). In healthy humans, only small amounts (≈ 0.5 mg/day) of Zn are excreted via urine (Swedish Environmental Protection Agency, 2011).

Previous studies in Ghana have indicated that, the exposure status of Zn and Cu cannot be evaluated adequately using urine as a marker, and suggested the need for the collection of data from other markers, such as blood and feces (Itai *et al*., 2014). Therefore, there is the need for caution in interpreting the urinary Zn and Cu results of this study. Except for urinary Zn levels observed for the Ashaiman and Tema e-waste workers, the elevated Zn concentrations recorded for the Agbogbloshie e-waste workers compares favourably with Caravanos *et al*. (2013) findings in Accra. Previous studies by Asante *et al*., (2012) in Ghana and Wang *et al*. (2011) in China, reported high mean Cu concentrations in urine of e-waste exposed group compared with control groups, but found no significant difference in the level of urinary Cu between the exposed and control groups in their studies.

Regarding urinary Sb levels, it was observed that the Agbogbloshie, Ashaiman and Tema e-waste participants recorded relatively low urinary Sb levels than that of the control group (shown in Table 5.7 and Figure 5.11). Statistically significant difference was observed for only Sb levels between the control group and the Tema e-waste participants. The relatively low mean Sb level observed for the e-waste subjects compared with that of the control group suggests non-specific exposure to Sb in e-waste workers at the three respective e-waste sites under this study.

Antimony is a human carcinogen and known to cause liver, skin, and respiratory and cardiovascular diseases (Itai *et al*., 2014). Industrial activities such as smelting of mineral ores, and the use of antimony products like flame retardants and alloys are the main sources of antimony in the environment are (Itai *et al*., 2014). Occupational exposure to Sb mainly occurs via inhalation and skin contact (De Boeck *et al*., 2003; Asante *et al*., 2012). However, since antimony is also found naturally in the environment, the general population is exposed to low levels of it every day, primarily in food, drinking water, and air (ATSDR, 1995).

Figure 5.11: Comparison of Sb concentrations in urine of e-waste workers with control group.



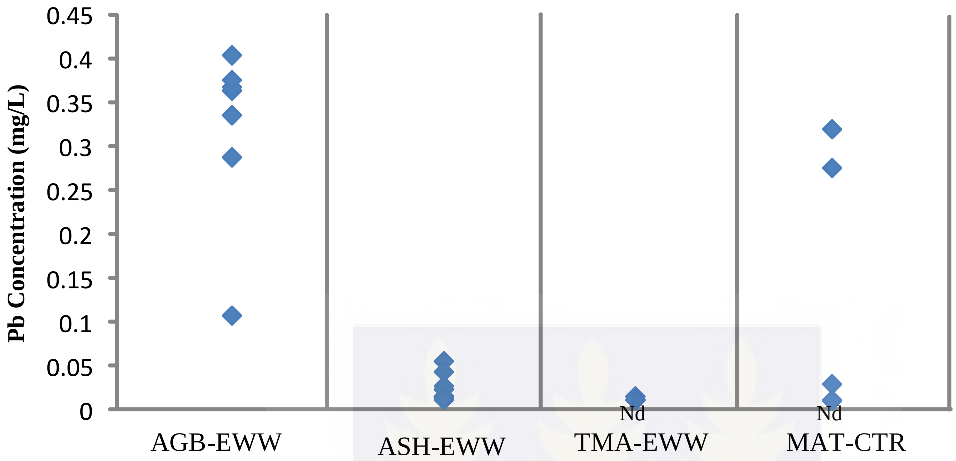
Source: Author's Feldwork (2013).
Nd means not detected.

Similar to that observed for urinary Sb, urinary Cd level observed for the control group was more than that of all the e-waste participants involved in this study. Notably, except for one female child (0.08 mg/L) from the control group, urinary Cd levels were below detection limits for all the twenty four e-waste subjects and the remaining seven subjects from the control group involved in this study. Thus, suggesting that, e-waste recycling practices at the respective e-waste sites might not have presently influenced Cd exposure levels in e-waste workers at these sites. The generally low or absent Cd levels in urine of the subjects involved in this study is not surprising because the soil results of this study also showed that except for mercury, soil mean Cd levels observed for the all the three respective e-waste sites (and the control site) were relatively lower than the concentrations observed for the other metals analysed in this study.

The major source of Cd in the general population is food (Klaassen and Watkins, 2003 in Heo and Lee, 2013). Cadmium is also absorbed in the body by inhaling air which is polluted by environmental tobacco smoke, house dust, and industrial emissions (Zheng *et al*., 2008). Cadmium is a cumulative toxicant and the kidney is considered the critical target organ, for both the general population and occupationally exposed populations (UNEP, 2010). Low levels of cadmium exposure was associated with renal damage and once thought to be mostly an occupational hazard (Bressler *et al*., 2004 in Zheng *et al*., 2008), but attention has now focused on the general population (Zheng *et al.*, 2008). The relatively high urinary Cd concentration recorded for the control group than that of the e-waste workers, is in line with Caravanos *et al*. (2013) findings in Accra, but contrary to Wang *et al*., (2011) study results in China. Previous results by Asante *et al*., (2012) showed that Agbogbloshie e-waste recyclers had relatively high mean urinary Cd concentration than the reference (control) group in Accra but lower than that observed for a second reference (control) group in Obuasi in Ghana.

Concerning urinary Pb concentrations (Figure 5.4), it was observed that Pb level in urine of Agbogbloshie e-waste workers (range: 0.108 - 0.404 mg/L) was significantly higher compared with that of control group (range: <0.001 - 0.32 mg/L). This suggests exposure of Agbogbloshie e-waste work to high Pb levels as a result of crude e-waste recycling activities and environmental contamination at the e waste site. Lead has adverse effects in multiple organs and can cause neurological, cardiovascular, renal, gastrointestinal, haematological and reproductive effects (UNEP, 2010). Of particular concern, is lead exposure in children, which is linked to a lower intelligence quotient (IQ), behavioural effects and learning disabilities (Brigden *et al*., 2008; UNEP 2010).

Figure 5.12: Comparison of Pb concentrations in urine of e-waste workers with control group.



Source: Author's Feldwork (2013).
Nd means not detected.

Though not statistically significant, Pb levels in urine samples from both Ashaiman (0.012 - 0.056 mg/L) and Tema e-waste workers (range: <0.001 - 0.016 mg/L) were found to be low compared with the that of the control group, comparing favourably with Wang *et al.*, (2011) study results in China. The relatively low Pb level observed for these e-waste workers suggests that e-waste recycling activities at both Ashaiman and Tema e-waste site may not have influenced exposure levels in the e-waste workers at the two respective e-waste sites.

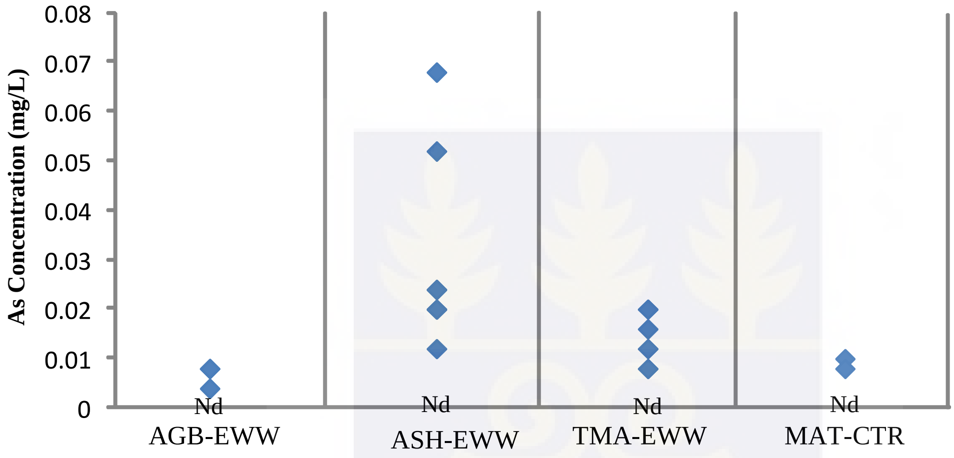
Lead like, copper, zinc, antimony, cadmium, arsenic and mercury have known uses in electrical and electronic equipment and therefore exposure of these metals to the e-waste workers and their related human health effects are of concern. Lead is not required for human health, and is highly toxic to humans, even at low exposure levels (Bellinger & Dietrich, 1994; ATSDR, 2007; Brigden *et al.*, 2008). Exposure to lead occurs mainly through inhalation of dust and air and ingestion of foodstuffs, water and dust (UNEP, 2010). Lead is accumulated in bone through repeated exposures and may serve as a source of exposure later in life.

Comparing urinary arsenic levels of e-waste workers with the control group, it can be noticed in Table 5.7 and Figure 5.13 that urinary mean As levels recorded for the Ashaiman (0.028 mg/L) Tema (0.012 mg/L) and Agbogbloshie (0.006 mg/L) e-waste workers were high compared with that of the control group. This finding is contrary to the study results by Asante *et al.* (2012) in Ghana. Notably, whereas one subject each from the three respect e-waste sites under this study, had urinary As below detection limits, six out of the eight control subjects had urinary As below detection limits. Exposure to arsenic occurs mostly in the workplace, near hazardous waste sites, or in areas with high natural levels (www.lef.org).

Statistically, it was observed that unlike the Tema and Agbogbloshie e-waste subjects, urinary As excretion level recorded for Ashaiman e-waste subjects was significantly high compared with that of the control group. This suggests that e-waste workers at the Ashaiman e-waste waste site may be highly exposed to arsenic due to e-waste recycling activities at the e-waste site. Contaminated soil may be a potential source of arsenic exposure (WHO, 2001). However, there is the need for caution when interpreting this result because there could be other sources of exposure for As levels in e-waste participants other than e-waste activities.

For instance, consumption of seafood may contribute intakes of As because seafood has high As concentrations and As is predominately present as organic species such as arsenobetaine (Cullen and Reimer, 1989 in Asante *et al*., 2007). Arsenobetaine which is ingested thorough the seafoods is rapidly excreted into urine without change (Le *et al*., 1993 in Asante *et al*., 2007). Smokers are also exposed to arsenic by the inhalation of mainstream cigarette smoke (http://www.who.int/mediacentre/factsheets/fs372/en/index.html). Soluble inorganic arsenic is acutely toxic, and ingestion of large doses leads to gastrointestinal symptoms, disturbances of cardiovascular and nervous system functions in humans, and eventually death (WHO, 2001). In survivors, bone marrow depression, haemolysis, hepatomegaly, melanosis, polyneuropathy and encephalopathy may be observed (WHO, 2001). Currently, countries which have occupational regulations for arsenic have set the limit for inorganic arsenic between 0.01 and 0.1 mg/m^3 (WHO, 2001).

Figure 5.13: Comparison of As concentrations in urine of e-waste workers with control group.



Source: Author's Feldwork (2013).
Nd means not detected.

Regarding urinary mercury, Table 5.7 shows that all the e-waste subjects as well as the control subjects involved in this study had urinary mercury below detection limits, which is in line with previous study in Ghana by Asante *et al*., (2012). Mercury has no biochemical or nutritional value, and its compounds are highly toxic and accumulative, especially to developing nervous system (UNEP, 2002). The non-detection of urinary mercury in this study, suggests non-occupational exposure of Agbogbloshie, Ashaiman and Tema e-waste to Hg from e-waste recycling activities at all the respective e-waste sites under this study.

As indicated earlier, mercury was relatively the metal with the least concentration in soil at all the sites under this study, hence the non-detection of urinary mercury from all the subjects is not so surprising. However, since the e-waste workers are still engaged in crude e-waste processing activities without any regard to even their health, there is the need for continuous monitoring at the e-waste sites.

5.3.6. Relationship between heavy metals concentration in urine and human behaviour

As indicated earlier in chapter four, the socio-demographic variables (Tables 4.5 and 4.6) used in this study included factors that are likely to influence urinary heavy metal levels, such as smoking, alcohol drinking, and years of engagement in e-waste processing. Table 5.8 shows the relationship between the related factors and urinary metals concentrations of the twenty four e-waste subjects involved in this study. Table 5.9 also shows the relationship urinary heavy metals levels of the control group and the related factors.

Table 5.8: Distribution of mean heavy metals concentrations in urine of e-waste workers from the Accra - Tema Metropolis by age, smoking habit, alcohol drinking, e-waste activity and working years.

	----------------------------------mg/L--------------------------------						
Related Factor	**Cu**	**Zn**	**Sb**	**Pb**	**As**	**Cd**	**Hg**
Age (years)							
10 - 14	0.808	0.188	0.784	0.328	0.006	Nd	Nd
15-19	0.464	0.079	0.610	0.184	0.018	Nd	Nd
20 - 24	0.245	0.049	0.478	0.109	0.015	Nd	Nd
25 and above	Nd	Nd	0.202	0.011	0.018	Nd	Nd
Smoking							
Yes	0.473	0.093	0.561	0.190	0.009	Nd	Nd
No	Nd	Nd	0.3232	0.01785	0.0237	Nd	Nd
Alcohol drinking							
Yes	0.527	0.096	1.109	0.148	0.006	Nd	Nd
No	0.241	0.049	0.370	0.114	0.017	Nd	Nd
E-waste Activity							
OB only	0.838	0.168	0.698	0.353	0.007	Nd	Nd
DM+OB	0.188	0.032	0.795	0.052	0.014	Nd	Nd
CL+DM+OB	Nd	Nd	0.251	0.00388	0.014	Nd	Nd
CL+DM	Nd	Nd	0.225	0.015	0.023	Nd	Nd
Work Experience							
1 - 3 years	0.326	0.076	0.602	0.141	0.022	Nd	Nd
4 - 6 years	0.337	0.056	0.409	0.136	0.009	Nd	Nd
over 10 years	Nd	Nd	0.244	0.01525	0.015	Nd	Nd

Source: Author's Feldwork (2013).

Nd means not detected.

Based on the results, it is evident that except for As, highest mean concentrations for the elements determined in urine of the twenty four e-waste participants, particularly, Pb, Cu, Zn, and Sb, were observed for children of the age group of 10 - 14 years, followed by those with ages ranging from 15 to19 years, 20 to 24 years and then 25 years and above. Notably, Urinary Cu and Zn levels were observed to be below detection limits for all e-waste workers who were 25 years and above (Table 5.8). Children within the age of 10 -14 years recorded the least mean urinary As concentration. Mean urinary As level for e-waste workers within the age group of 15 - 19 years was found to be slightly higher or same for those within the age group of 25 years and above (Table 5.20). As mentioned earlier urinary Cd and Hg were below detection limits for all the e-waste workers involved in this study and were therefore excluded from this analysis.

Table 5.9: Distribution of mean heavy metals concentrations in urine of control group by age, sex alcohol drinking habits.

	----------mg/L----------						
Related Factor	**Cu**	**Zn**	**Sb**	**Pb**	**As**	**Cd**	**Hg**
Age (years)							
10 - 14	Nd	Nd	1.806	Nd	Nd	0.08	Nd
Above 20 years	0.525	0.052	0.703	0.108	0.003	Nd	Nd
Alcohol drinking							
Yes	0.332	0.024	1.075	0.015	0.005	Nd	Nd
No	0.415	0.044	0.947	0.103	0.002	Nd	Nd
Sex							
Female	Nd	Nd	2.014	Nd	Nd	0.08	Nd
Male	0.525	0.052	0.634	0.108	0.003	Nd	Nd

Nd means not detected. *Source: Author's Fieldwork (2013).*

Statistically, it was observed that except for urinary As and Sb level, urinary Pb, Cu, and Zn concentrations recorded for children (10 - 14 years) were significantly more compared with only those recorded for adults with ages ranging from 25 years and above. This suggests that children at e-waste sites in the Accra - Tema Metropolis, especially at the Agbogbloshie e-waste site, are most likely to be exposed to significant levels of Pb, Cu, and Zn from as a result of environmental contamination from e-waste processing activities. Ingestion of heavy metals, for example, lead (Pb) in dust and soil is a major exposure pathway in children, due to their biological characteristics and behavioural patterns such as hand to mouth activities (UNEP, 2010).

Lead exposure in children is of major concern. Lead is linked to a lower intelligence quotient (IQ), behavioural effects and learning disabilities (Brigden *et al*., 2008; UNEP, 2010). In adults, lead can increase blood pressure and cause fertility problems, nerve disorders, muscle and joint pain, irritability, and memory or concentration problems. According to Horne and Gertsakis (2006), evidence on the detrimental effects of lead in children at low levels has increased, and the US Centers for Disease Control and Prevention (CDC) "level of concern" for children at 1 microgram per litre has become increasingly questioned, as there is currently arguably no demonstrably safe level of exposure for children.

For the control group, it can be observed in Table 5.9 that urinary mean Pb, Cu, Zn, and As levels in urine of the two children (ages: 11 and 13 years) involved in this study were below detection limits, hence relatively lower than those of the adults with ages ranging 23 - 52 years, though no significant difference in urinary metal levels were observed between them. However, urinary mean Sb and Cd levels recorded for the children from the control group were found to be relatively higher than that of the adults. Notably, the only urinary Cd recorded in this study was observed for a 13 year old female child from the control group. Cadmium is a cumulative toxic metal that has been well documented in children (Friedmana *et al*., 2006 in Zheng *et al*., 2008). Smoking or passive smoking can be a source of non-occupational exposure to cadmium in humans (Satarug *et al*., 2000 in Zheng *et al*., 2008).

Regarding e-waste workers smoking habits, the results showed that generally urinary Pb, Zn, Cu, levels recorded for cigarette smokers (Table 5.20) was significantly more than those of non-smokers. This suggests that generally cigarette smoking might have influenced Pb, Zn, and Cu levels in the e-waste participants who smoke. Notably, whereas none of the ten non-smokers had Cu and Zn detected in their urine samples, only 6 out of the 14 e-waste workers who smoke, had Cu and Zn below detection limits. As shown Table 5.20 urinary mean Sb level recorded for smoking e-waste workers was more than that of non-smokers, though no significant difference were observed between them. On the other hand, it was observed that non-smoking e-waste workers recorded higher mean urinary As level than that of smoking e-waste workers, suggesting that smoking could not have influenced the observed As levels in urine of e-wastes. Smokers are exposed to arsenic by the inhalation of mainstream cigarette smoke (http://www.who.int). As mentioned earlier, all the respondents in the control group are non-smokers so no analysis was carried out for the control group with regard to smoking.

For alcohol drinking, it was observed that, except for Pb and As, mean Sb, Cu and Zn levels in urine of e-waste subjects who drink alcohol were higher compared with that of those who do not drink alcohol. Notably, about 71 percent of 21 e-waste participants who do not drink alcohol had urinary Cu and Zn below detection limits. No significant differences were observed for any of the urinary metal levels between alcohol drinkers and non-alcohol drinkers. This suggests that alcohol consumption did not significantly influence the observed heavy metal levels in urine of e-waste subjects.

Considering number of years in e-waste processing activities as a relevant factor, it was observed that generally, e-waste participants with relatively few number of year in engagement in e-waste processing activities (i.e. between 1 to 3 years) recorded the highest mean concentrations for most of the metals (Pb, Zn, Sb, As) analysed (Table 5.8), compared with those with 4 - 6 and over 10 years work experience, though no significant differences were observed between them. It was also observed that, without any significant difference, urinary mean Cu concentration recorded for e-waste workers with 4 - 6 years work experience was relatively higher than e-waste workers with 1 - 3 years and over 10 years work experience. Thus the least mean urinary Pb, Zn, Sb and Cu concentrations were recorded for those with over 10 years of engagement in e-waste processing, and that for As was recorded by those with 4 -6 years of e-waste work experience.

Considering type of e-waste processing activity as a relevant factor, the results showed that, the 7 out of 24 e-waste participants who solely involved the Open Burning (OB) of e-waste , followed by those (4 out of 24) engaged in both Dismantling and Open Burning (DM+OB) recorded the highest mean concentrations for most (3 out of 5) of the metals detected in urine of e-waste participants, particularly, Pb, Cu , and Zn. Urinary Zn and Cu were observed to be below detection limits for the engaged in both e-waste Collection and Dismantling (CL+DM) as well as those engaged in all three e-waste processing activities (Collection, Dismantling and Open Burning (CL+DM+OB) (Table 5.8).

This suggests that generally, e-waste workers engaged in the open burning, followed by those engaged in dismantling of e-waste are more likely to be exposed to heavy metals from their activities than those engaged in the collection of e-waste. The results also showed that e-waste participants engaged in both CL+DM activities recorded relatively higher urinary mean Pb concentrations than those engaged in CL+DM+OB activities (Table 5.8).Regarding urinary Sb, it was observed that e-waste participants engaged in DM+OB, followed by those engaged in solely OB recorded relatively more mean urinary Sb levels than those engaged in CL+DM+OB and CL+DM in that order (Table 5.8). For arsenic, Table 5.8 shows that, the least and highest mean urinary As concentrations of e-waste participants, were recorded by those engaged in OB only and CL+DM respectively. Urinary mean As concentration recorded for those engaged in DM+OB and CL+DM+OB were observed to be the same (Table 5.8).

Statistically, except for Sb and As levels, urinary Pb, Zn and Cu levels recorded for e-waste subjects engaged in solely OB activities were found to be significantly high compared with those engaged in DM+OB, CL+DM+OB and CL+DM activities. This suggests that e-waste workers engaged in solely open burning activities are more likely to be exposed to high levels of heavy metals from e-waste recycling activities. No statistically significant difference were observed for heavy metals (Pb, Zn, Cu, As and Sb) levels between e-waste subjects engaged in DM+OB, CL+DM+OB and CL+DM. No analysis was done for the e-waste workers with regard to sex as they were all males (Appendix E2). However, for the control group, it was noticed that Sb levels in urine of female subjects were significantly more compared with the male subjects. Again, although the male subjects from the control group recorded relatively high mean levels for the rest of the metals analysed (Cu, Zn, Pb, As) (Table 5.21) compared with females, no significant differences were in heavy metals levels observed between them.

5.4 Summary

This chapter presented and discussed the results from the interviews, observations, and laboratory analysis of heavy metals concentrations in environmental (soil) and biological (urine) samples. Current e-waste management practices by informal e-waste workers have led to significant heavy metals contamination of soil at the selected e-waste sites and also influenced certain heavy metals levels in urine of most e-waste participants in this study. Significantly higher Pb, Sb, As, Hg and Zn concentrations were found in soils from the e-waste recycling sites in the Accra - Tema Metropolis compared with the control site. Furthermore, significantly higher levels of Pb, Cu and Zn and Sb were found in urine of e-waste workers compared with those of the control group. In the next chapter, the conclusion of the findings of this study is made and recommendations are provided for policy considerations.

CHAPTER SIX

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1. Introduction

Previous chapters provided insight into the data analysed for this study; looking at the flows of UEEE imports and management practices at the ports. It also integrated the handling processes at the e-waste sites, and explained some of the externalities embedded in the e-waste management practices. This penultimate chapter presents the summary of this study, draws some conclusions from the analyses and provides some recommendations for policy consideration.

6.2 Summary

As already highlighted, the quest for socio-economic development in recent times have warranted the use of EEE. However, the increasing use of electrical and electronic gadgets is also leading to the generation of e-waste. Meanwhile developing countries like Ghana, lack established national management and control systems for such wastes, leading to the informal management of e-waste. This study therefore analysed the flow of UEEE imports to Ghana and how such imports are handled and managed at the ports of entry and e-waste processing sites in the Accra - Tema Metropolis. It also aimed to understand the externalities of the current e-waste management practices with regard to environment and human health.

To achieve these goals, data for this study were obtained from both primary and secondary sources. Data were collected by adopting multiple methods of data collection namely interviews, observations and review of documents. Urine samples from e-waste workers and soil samples from the Agbogbloshie, Ashaiman and Tema e-waste recycling sites, as well as those from a control site/ group were also collected and analysed in the laboratory for the presence and concentrations of heavy metals.

6.3. Conclusions

Based on the methodology used, the study found that the significant amount of UEEE import flows to Ghana is largely from economically developed countries in the Global North, particularly countries in Europe and North America. Flows from the United Kingdom, followed by the United States of America and Italy accounted for relatively the larger share of UEEE imports. However, there is an emerging flow of such imports to Ghana from relatively less economically developed countries in the Global South, such as countries in Asia and Africa. This finding tends to complicate but does not oppose the study hypothesis that Ghana (a developing country) has become a pollution haven for e-waste. In other words, although the larger share of UEEE (and by implication e-waste) imports are from relatively richer countries with GDP higher than Ghana's, some of the import flows of these equipment also originate from poorer countries with GDP lower than Ghana's. Thus, the study found a partial support for the Pollution Haven Hypothesis with regard to the international flow of e-waste shipments to Ghana.

The study also found that, although some of these UEEE imports are in good working condition upon arrival at the Tema Port, some are damaged and repairable or beyond repairs and therefore e-waste. The study revealed that effective mechanisms for controlling and managing obsolete or non-functional UEEE import flows in Ghana are currently non-existing as enforcement officials at the Tema Port lack the requisite or adequate logistical, technical and legal capacity to effectively handle or tackle such flows. Nevertheless, the importation of UEEE, irrespective of whether it is functioning or obsolete, contributes to national economy.

Besides the revenue that government generates by way of duty paid on importation of certain second hand electrical and electronic equipment such as microwaves and televisions, the subsequent sale of these imported items to consumers, whether tested or non-tested, is a good source of revenue generation for both importers and retailers of these products, and also offers some form of economic benefits to consumers since such products are relatively less expensive.

The study further shows that, very often, importers and retailers of second hand electrical and electronic items rely on informal e-waste workers or scrap dealers for the disposal of their used electrical and electronic imports that are non-functional or e-waste. Thus, due to the absence of a well-established formal e-waste management system, non-functioning used electrical and electronic equipment or e-waste imports may eventually end up at open dumpsites or informal e-waste recycling sites. Despite the fact that importers and retailers of UEEE are sometimes faced with the risk of making a loss or relatively lower profit from untested UEEE imports which might not be functioning upon arrival, the subsequent release or sale of the non-functioning or obsolete UEEE to informal e-waste workers or scrap dealers also offers a livelihood opportunity to these e-waste workers who recover valuable e-waste fractions for sale.

However, based on the findings of this study, it is evident that the current crude e-waste management practices at informal e-waste scrap yards / recycling sites have led to the release of significant levels of heavy metals into soil which could subsequently contaminate nearby water bodies through leaching, and may also expose e-waste workers and possibly nearby residents to human health risks. Based on the type of e-waste processing being conducted at e-waste sites, the study revealed that to some extent, the concentrations of heavy metals in soil vary among e-waste sites in the Accra - Tema Metropolis. The heavy metals (Pb, Sb, Cu, Zn, Cd, As and Hg) soil analysis in this study show that, the levels between the Tema e-waste dismantling site and the dismantling stations of Agbogbloshie and Ashaiman e-waste site were not significantly different, except for As and Pb levels, which were found to be significantly higher and lower respectively at the Tema e-waste dismantling site compared with those of the dismantling station at the Agbogbloshie e-waste site.

It was also found that soil heavy metals (Pb, Sb, Cu, Z, Cd, As and Hg) levels recorded for samples from the open burning station at the Agbogbloshie e-waste site were not significantly different compared with those from the open burning station at the Ashaiman e-waste site. Elevated levels of soil Pb and Sb were observed for the disposal station at the Agbogbloshie e-waste site compared with the Ashaiman e-waste disposal station. Apart from these two metals, none of the heavy metals levels showed any significant difference between the disposal stations of Agbogbloshie and Ashaiman e-waste sites.

This study also found that Pb and Zn levels recorded for the soil samples from the dismantling, open burning and disposal stations at Agbogbloshie e-waste site were significantly higher compared with those from a non-e-waste processing control site at Mataheko in Accra. It was also observed that the disposal station at the Agbogbloshie e-waste site had significantly higher soil Sb and Hg concentrations compared with the control site. Similarly, Pb concentrations in soil from the open burning station at the Ashaiman e-waste site as well as Zn and As concentrations recorded for soil from the Tema e-waste dismantling site were observed to be significantly higher compared with those of the control site. This indicates that the crude e-waste processing practices in the Accra-Tema metropolis have contributed significantly to Zn, Pb, As, Sb and Hg contamination in soil at the respective e-waste scarp yards/ recycling sites in this study.

The results further indicate that, in general, except for Zn and As levels, mean Sb, Cd and Hg concentrations observed for Ashaiman, Agbogbloshie and Tema e-waste exceeded the Dutch target values for these metals in soil. Furthermore, mean Pb concentrations recorded for soils from both Ashaiman and Agbogbloshie e-waste sites and Cu mean value observed for the Tema e-waste site were found to be higher than the Dutch target values for these metals. Thus, emphasizing that crude e-waste processing activities have resulted in heavy metals contamination at e-waste sites in the Accra-Tema metropolis. It was also observed that the level of soil Sb contamination at all the e-waste sites in this study is severe as the respective e-waste sites had mean Sb values exceeding the Dutch intervention value (15 mg/kg dry weight) for this metal. This suggests that humans, plants and animals at the selected e-waste sites in this study may be seriously at risk of Sb exposure from e-waste processing activities.

This study also assessed the levels of heavy metals in human urine, and found elevated Cu, Zn and Pb levels in e-waste workers from the Agbogbloshie e-waste site compared with those from the Ashaiman and Tema e-waste sites, suggesting relatively higher level of metal exposure at the Agbogbloshie e-waste site than the Ashaiman and Tema e-waste sites. Elevated As concentrations were also found in urine of e-waste workers from the Ashaiman e-waste site compared with those from the Agbogbloshie e-waste site.The results further showed that urinary Sb levels in e-waste workers from the Tema e-waste dismantling site were significantly low compared with the control group, suggesting that e-waste recycling activities might not have influenced Sb levels in the e-waste workers at the Tema e-waste dismantling site.

However, elevated levels of Pb, Cu and Zn were found in urine of e-waste workers from the Agbogbloshie e-waste site compared to those from a control site. This suggests exposure of these metals to e-waste workers at the Agbogbloshie e-waste site from environmental contamination related to crude e-waste recycling practices and poses a threat to their health. Similarly, elevated As concentration was found in urine of e-waste workers from the Ashaiman e-waste site compared to those from the control site, which might imply As exposure to e-waste workers at the Ashaiman e-waste site due to the crude e-waste processing activities which could have adverse health implications for the e-waste workers.

6.4. Recommendations

To effectively address the issue of e-waste imports and management in Ghana, it is recommended that Government should review and expedite action on the passage of the 2011 draft Hazardous Waste and Electronic Waste Management Bill into law.

While awaiting the enactment of a national legislation on e-waste, it is important for the Energy Commission, the Environmental Protection Agency and other relevant enforcement agencies to improve enforcement of existing policies and legislations related to e-waste imports and management such as the Energy Efficiency Regulations, 2008 and the Environmental Protection Agency Act, 1994 (ACT 490). Recognising the existing energy crisis confronting the country, the recent seizure of large volumes of imported used fridges and refrigerators by the Energy Commission, as required by law, is commendable and must be continued while providing alternative systems for Ghanaians to purchase brand new electronic products at affordable prices.

To monitor and prevent the shipments of non-functional UEEE or e-wastes to Ghana, there is also the need for Government to provide appropriate and sufficient logistical support for the relevant regulatory authorities in the port, particularly Customs, EPA, GSA, Energy Commission, and National Security. Facility for testing for functionality of imported used electrical and electronic equipment should be provided for use in the port. Government should also ensure building of technical capacity of adequate number of enforcement officials in e-waste shipments inspection, detection and prevention. Also, importers of used electrical and electronic equipment should be made to accompany their electronic imports with functionality test certificates.

Furthermore, it is important for the Customs Division of the Ghana Revenue Authority, EPA, GSA, Energy Commission, National Security, GPHA and other relevant regulatory agencies to foster and strengthen collaborations among themselves as well with other international enforcement agencies including Interpol in monitoring and preventing the shipments of e-waste to Ghana. Exchange of expertise and sharing of information and intelligence among relevant enforcement authorities are deemed to be useful collaborative approaches in tackling the issue of transboundary e-waste shipments.

To reduce or prevent the inflows of non-functional electrical and electronic equipment or e-waste imports into Ghana, it is also important that relevant enforcement authorities at the port forge collaboration with private ports and maritime stakeholders including shipping lines, terminal operators, importers and freight forwarders / clearing agents. Furthermore, importers of used electrical and electronic equipment should be educated on the need to test the functionality of UEEE prior to import, and import only functional used electrical and electronic products to Ghana.

To ensure the protection of human health and the environment from the dangers associated with improper e-waste management, the Ghana EPA, Metropolitan Assemblies and Municipal Authorities should as a matter of urgency, begin to embark on frequent monitoring of activities of informal e-waste workers at the e-waste scrap yards / recycling sites and ensure that the e-waste workers comply with existing laws on environment, health and safety. Particular attention should be given to existing laws prohibiting open burning of waste, and stricter punitive actions should be given to offenders who persist to engage in such illegal act. The relevant authorities should ensure that e-waste workers use appropriate personal safety equipment when carrying out e-waste processing activities. There is further the urgent need for clean-up of contaminated soils at the informal e-waste dump sites / recycling sites.

Government should partner civil societies such as GreenAd, Blacksmith Institute and other interested organisations to provide informal e-waste workers with requisite training in environmentally sound processing of e-waste, using simple tools. More importantly, there is the need for the establishment of a coordinated e-waste collection and recycling system in Ghana, involving both the formal and informal sectors. Government should promote, partner and provide incentives for the private sector to establish e-waste recycling processing plants in the country. Sustainable measures should also be put in place to provide e-waste workers with alternative and attractive source of livelihood.

Furthermore, there is the need for the EPA and the Metropolitan Assemblies and Municipal Authorities to collaborate with Civil Societies groups such as Ports Environmental Network-Africa (PENAf) and GreenAd to increase awareness of UEEE importers, retailers, consumers, informal e-waste workers and the general public on the dangers associated with improper e-waste disposal and recycling.

Last but not least, this study recommends for a comprehensive study on the role of informal sector in the e-waste recycling and how that can be adapted, modified and incorporated into the whole formal waste management system. Situation where the informal sector is seen as a nuisance appears to be exacerbating the fight against improper e-waste management as exemplified in Agbobloshie and Tema. It is further recommended that a comprehensive study should be conducted to ascertain the long term environmental and health impacts of the current e-waste management practices in the country.

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APPENDICES

Appendix A1

NOGUCHI MEMORIAL INSTITUTE FOR MEDICAL RESEARCH
Established 1979
A Constituent of the College of Health Sciences
University of Ghana

INSTITUTIONAL REVIEW BOARD

Phone: +233-302-916438 (Direct)
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Fax: +233-302-502182/513202
E-mail: nirb@noguchi.mimcom.org
Telex No: 2556 UGL GH

Post Office Box LG 581
Legon, Accra
Ghana

My Ref. No: DF.22
Your Ref. No:

3rd July, 2013

ETHICAL CLEARANCE

FEDERALWIDE ASSURANCE FWA 00001824 **IRB 00001276**

NMIMR-IRB CPN 106/12-13 **IORG 0000908**

On 3rd July 2013, the Noguchi Memorial Institute for Medical Research (NMIMR) Institutional Review Board (IRB) at a full board meeting reviewed and approved your protocol titled:

TITLE OF PROTOCOL : **A study of electronic waste imports and management in the Accra-Tema Metropolis**

PRINCIPAL INVESTIGATOR : **Henry Ayikai Okine, MPhil Cand.**

Please note that a final review report must be submitted to the Board at the completion of the study. Your research records may be audited at any time during or after the implementation.

Any modification of this research project must be submitted to the IRB for review and approval prior to implementation.

Please report all serious adverse events related to this study to NMIMR-IRB within seven days verbally and fourteen days in writing.

This certificate is valid till 2nd July, 2014. You are to submit annual reports for continuing review.

Signature of Chair: ....
Mrs. Chris Dadzie
(NMIMR – IRB, Chair)

cc: Professor Kwadwo Koram
Director, Noguchi Memorial Institute
for Medical Research, University of Ghana, Legon

Appendix A2

GHANA PORTS AND HARBOURS AUTHORITY
PORT OF TEMA

P.O. Box 488
Tema, Ghana
Telephone: (233) 22 - 202631-8 / 22 204385-8
Fax: (233) 22 - 204136
Website: www.ghanaports.gov.gh
Email: tema@ghanaports.net

OUR REF.: DP.TM/T9/Vol.2/922 APRIL 15, 2013

THE DIRECTOR
INSTITUTE FOR ENVIRON. & SANITATION STUDIES
P. O. BOX LG 209
LEGON - ACCRA

Dear Sir,

RE: INTRODUCTORY LETTER
HENRY A. OKINE

Your letter dated March 17, 2013 on the above subject refers.

We wish to inform you that approval has been given for your student, **Henry A. Okine** to collect information for his project work on "**A study on E-Waste Imports and Management in the Accra-Tema Metropolis**".

You are kindly required to furnish us with a copy of the completed research work for our study.

By copy of this letter, the Port Monitoring Manager and the Estate & Environ. Manager are kindly requested to give **Henry A. Okine** the necessary assistance.

In addition, the Port Security Manager is kindly requested to allow him entry into the Port from 15th April, 2013 to 15th May, 2013 to conduct his research work.

Yours faithfully,
FOR: GHANA PORTS & HARBOURS AUTHORITY

15/04/13

SAMUEL A-N. ADJAR
PORT PERS./ADMIN. MANAGER
FOR: AG. DIRECTOR OF PORT (TEMA)

Cc: *Port Monitoring Manager, Tema*
Estate & Environ. Manager, Tema
Port Security Manager, Tema
P/Copy

Appendix B

Soil sampling points Geographic Coordinates

Agbogbloshie E-waste Site	
Latitude	**Longitude**
05°33’.03.0”N	000°13’30.9”W
05°33’04.0”N	000°13’31.0”W
05°33’04.8”N	000°13’30.7”W
05°33’08.9”N	000°13’29.2”W
05°33’09.0”N	000°13’29.1”W
05°33’08.8”N	000°13’29.1”W
05°33’08.9”N	000°13’28.9”W
05°33’12.5”N	000°13’26.0”W
05°33’12.6”N	000°13’26.1”W
05°33’12.6”N	000°13’25.9”W
05°33’12.7”N	000°13’25.8”W
Ashaiman E-Waste Site	
Latitude	**Longitude**
05°41’00.7”N	000°01’41.8”W
05°41’01.0”N	000°01’41.2”W
05°41’01.3”N	000°01’40.2”W
05°41’00.5”N	000°01’41.4”W
05°41’00.2”N	000°01’43.0”W
05°41’00.0”N	000°01’42.9”W
05°41’00.1”N	000°01’43.2”W
05°40’59.8”N	000°01’43.1”W
05°41’00.3”N	000°01’42.9”W
05°41’00.2”N	000°01’42.9”W
05°41’00.1”N	000°01’42.8”W
05°41’00.3”N	000°01’42.7”W
Tema Community One E-waste Site	
Latitude	**Longitude**
05°38’35.1”N	000°00’01.3”E
05°38’35.1”N	000°00’01.2”E
05°38’35.1”N	000°00’01.1”E
05°38’35.0”N	000°00’01.1”E
Mataheko Control Site	
Latitude	Longitude
05°33’38.5”N	000°15’05.1”W
05°33’38.7”N	000°15’05.6”W
05°33’38.7”N	000°15’05.5”W
05°33’38.8”N	000°15’05.7”W

Appendix C

NUCLEAR CHEMISTRY AND ENVIRONMENTAL RESEARCH CENTRE

In case of reply the number and date of the letter should be quoted

Telephone: 0302 401 406
Fax: 233 302 400 807

Our Ref.: ....
Your Ref. No.:............................

National Nuclear Research Institute
Ghana Atomic Energy Commission
P.O.Box LG 80
Legon – Accra
Email:

28th January, 2014

The Director
Institute for Environment and Sanitation Studies
University of Ghana
Legon

Attention: Dr. Martin Oteng-Abobio
Dr. B.D. Ofori

Dear Sir,

CONFIRMATION OF MR. HENRY AYIKAI OKINE AAS ANALYTICAL RESULTS FOR HEAVY METAL ANALYSIS AT GAEC

Mr. Henry Ayikai Okine, a student of Institute for Environment and Sanitation studies University of Ghana, used our AAS facility to analyse soil and urine samples for heavy metal contamination as part of his M.Phil project work.

The period of analysis was March to July 2013.

Counting on your co-operation.

Yours faithfully,

MR. SAMUEL AFFUL
AG. MANAGER

THE MANAGER
NUCLEAR CHEMISTRY & ENVIRONMENTAL
RESEARCH CENTRE
NNRI/GAEC

Appendix D1

Import flow of used computers from the Top 50 exporting countries to Ghana, 2004 - 2010

Import Volume (Kg)

	Country of Export	2004	2005	2006	2007	2008	2009	2010	Total	%Total
1	United Kingdom	1366294	1730394	2014491	2264022	4925744	3001028.2	2776478.1	18078451	24.43
2	United States	1842049	1913977	1624534	1804213	4336581	1627274.5	1349274.1	14497903	19.59
3	Italy	187340	6646378	141374	214698	155533	244995.52	213557.67	7803876.2	10.54
4	Germany	456983	993647	360043	513531	1691775	346652.67	388493.12	4751124.8	6.42
5	France	186871	240434	252518	379048	243484	3041200.6	176597.63	4520153.3	6.11
6	Netherlands	817506	616986	699537	759606	547692	381838.15	437910.61	4261075.8	5.76
7	Belgium	411014	652046	508175	404571	360511	1195338.8	212217.81	3743873.6	5.06
8	Canada	362600	248903	282484	319073	1626353	269001.06	137976.84	3246390.9	4.39
9	China	113694	161331	311508	607431	517252	409460.39	449527.2	2570203.6	3.47
10	United Arab Emirates	345209	254216	286830	336230	531907	308171.96	325031.91	2387595.9	3.23
11	Denmark	377098	163195	66930	62823	48853	86962.91	119333.91	925195.82	1.25
12	Korea, Republic	49385	32835	43968	137899	264481	103532.13	87865.14	719965.27	0.97
13	Lebanon	71137	30951	84993	70120	135399	88807	64364.12	545771.12	0.74
14	Malaysia	25778	347	6616	4379	6392	454321	2693.67	500526.67	0.68
15	Australia	80647	8215	82604	97821	81949	57004.44	80707.3	488947.74	0.66
16	Norway	73840	68714	70831	86043	79530	44461.35	42983.25	466402.6	0.63
17	Guinea	200	1968	0	150	445559	67	74.81	448018.81	0.61
18	Spain	47227	106353	28228	82171	90137	55466.77	37711.18	447293.95	0.6
19	Hong Kong	16254	11130	19064	29553	51645	153692.81	152895.03	434233.84	0.59
20	Japan	70474	39156	51707	42419	62975	63859.51	80102.19	410692.7	0.55
21	Sweden	160630	18543	51884	52006	53182	25357.78	24925.13	386527.91	0.52
22	South Africa	57897	48652	77075	89288	38887	39707.87	213.27	351720.14	0.48
23	Ireland	186037	12309	35911	13792	31715	43304	18105.23	341173.23	0.46
24	Switzerland	79785	100517	22553	5304	102800	13398.18	4314.61	328671.79	0.44
25	India	4380	9765	6798	37453	31945	43437.5	72358.4	206136.9	0.28
26	Singapore	35039	12008	1572	11519	5259	61428.82	34306	161131.82	0.22
27	New Zealand	66414	22358	16278	9754	6459	7287.65	2908.01	131458.66	0.18
28	Nigeria	10092	4213	5077	11609	26188	14219.18	31106.41	102504.59	0.14
29	Israel	13886	7278	8746	11785	17306	22845.26	10016.23	91862.49	0.12
30	Turkey	17257	1843	32913	4955	4566	882.38	5345.14	67761.52	0.09
31	Finland	192	1961	6388	7480	13832	24223.19	12678.38	66754.57	0.09
32	Yugoslavia	0	371	0	0	0	76	52995.62	53442.62	0.07
33	Saudi Arabia	760	10493	8241	5831	12909	3874.03	7845.26	49953.29	0.07
34	Senegal	278	5326	3935	9657	3186	23768.21	1000.62	47150.83	0.06
35	Thailand	17613	3841	4889	4409	8914	961.46	1994.44	42621.9	0.06
36	Taiwan	11013	938	3544	1729	8194	608.09	5679.75	31705.84	0.04
37	Austria	959	2149	1835	6922	5385	3102.59	541.88	20894.47	0.03

	Country of Export	2004	2005	2006	2007	2008	2009	2010	Total	%Total
38	Indonesia	4456	679	5695	4869	84	4696	308.48	20787.48	0.03
39	Brazil	17	15603	80	375	508	968.22	68	17619.22	0.02
40	Cote D'ivoire	1312	1233	905	4370	43	5961	3471.97	17295.97	0.02
41	Greece	936	295	504	891	2447	4338.48	4616.71	14028.19	0.02
42	Portugal	8376	12	326	1703	1945	58.59	1558.96	13979.55	0.02
43	Morocco	2695	94	43	358	431	859	7833.2	12313.2	0.02
44	Sierra Leone	101	20	0	320	400	10531.58	392.82	11765.4	0.02
45	Niger	3908	0	1175	6217	15	0	400	11715	0.02
46	Mauritius	125	0	28	0	0	1686	8639.05	10478.05	0.01
47	Kenya	1012	411	495	1325	821	972.96	5292	10328.96	0.01
48	Botswana	2521	1091	2070	2562	402	345.92	784	9775.92	0.01
49	Netherlands Antilles	105	264	2694	6414	0	9	0	9486	0.01
50	Togo	0	1645	1783	2564	683	646	1081.71	8402.71	0.01

Source: Ghana CEPS (2010)

Appendix D2

Sources of Used Computer Imports to Ghana

Years / Import Volume (kg)

		GDP as of 2010	2004	2005	2006	2007	2008	2009	2010	Aggregate
Country of origin	**Region**	**USD**	**G Mass**	**G Mass**	**G Mass**	**G Mass**	**G Mass**	**G Mass**	**G Mass**	**Total G Mass**
Antigua & Barbuda	Caribbean	1,118.00	0.00	331.00	3338.00	59.00	0.00	0.00	0.00	3728.00
Bahamas	Caribbean	7,702.00	0.00	101.00	46.00	0.00	0.00	18.00	0.00	165.00
British Virgin Islands	Caribbean	909.00	25.00	71.00	307.00	0.00	0.00	0.00	0.00	403.00
Cayman Islands	Caribbean	3,208.00	0.00	0.00	0.00	86.00	0.00	0.00	2.50	88.50
Cuba	Caribbean	64,220.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00	100.00
Dominica	Caribbean	476.00	0.00	75.00	0.00	0.00	0.00	0.00	0.00	75.00
Dominican Republic	Caribbean	51,576.00	515.00	0.00	0.00	0.00	0.00	0.00	0.00	515.00
Guadeloupe	Caribbean	-	0.00	39.00	0.00	0.00	0.00	0.00	0.00	39.00
Jamaica	Caribbean	13,428.00	24.00	39.00	79.00	610.00	219.00	93.00	0.00	1064.00
Netherlands Antilles	Caribbean	4,078.00	105.00	264.00	2694.00	6414.00	0.00	9.00	0.00	9486.00
Puerto Rico	Caribbean	99,202.00	1130.00	0.00	0.00	0.00	0.00	0.00	0.00	1130.00
Monserrat		-	0.00	0.00	0.00	0.00	0.00	0.00	130.91	130.91
Belize	Central America	1,401.00	0.00	0.00	0.00	0.00	0.00	177.00	0.00	177.00
El Salvador	Central America	21,215.00	0.00	0.00	0.00	0.00	0.00	140.00	0.00	140.00
Mexico	Central America	1,032,220.00	0.00	7.00	200.00	129.00	273.00	473.00	4.50	1086.50
Nicaragua	Central America	6,551.00	0.00	0.00	1300.00	0.00	156.00	0.00	0.00	1456.00
Panama	Central America	26,777.00	0.00	0.00	1968.00	37.00	0.00	15.92	70.00	2090.92
Canada	Northern America	1,577,040.00	362600.00	248903.00	282484.00	319073.00	1626353.00	269001.06	137976.84	3246390.90
United States	Northern America	14,447,100.00	1842049.00	1913977.00	1624534.00	1804213.00	4336581.00	1627274.45	1349274.06	14497902.51
Argentina	South America	370,263.00	0.00	0.00	0.00	0.00	160.00	0.00	0.00	160.00
Bolivia	South America	19,640.00	0.00	0.00	0.00	0.00	61.00	0.00	0.00	61.00
Brazil	South America	2,088,970.00	17.00	15603.00	80.00	375.00	508.00	968.22	68.00	17619.22
Colombia	South America	288,086.00	0.00	0.00	12.00	0.00	300.00	0.00	5.36	317.36
Ecuador	South America	58,910.00	0.00	380.00	0.00	59.00	0.00	0.00	0.00	439.00
Guyana	South America	2,260.00	0.00	0.00	0.00	2051.00	0.00	0.00	0.00	2051.00
Peru	South America	157,324.00	60.00	0.00	380.00	665.00	0.00	0.00	63.91	1168.91
Uruguay	South America	40,265.00	755.00	31.00	0.00	0.00	0.00	0.00	0.00	786.00
Ethiopia	Eastern Africa	26,928.00	173.00	69.00	402.00	398.00	427.00	40.00	476.41	1985.41
Kenya	Eastern Africa	32,483.00	1012.00	411.00	495.00	1325.00	821.00	972.96	5292.00	10328.96
Madagascar	Eastern Africa	8,739.00	0.00	0.00	0.00	0.00	0.00	42.00	0.00	42.00
Mauritius	Eastern Africa	9,729.00	125.00	0.00	28.00	0.00	0.00	1686.00	8639.05	10478.05
Mozambique	Eastern Africa	9,533.00	0.00	0.00	0.00	0.00	78.00	109.00	0.00	187.00
Republic Of Djibouti	Eastern Africa	1,140.00	0.00	0.00	0.00	0.00	0.00	35.00	8164.66	8199.66

Country of origin	Region	GDP as of 2010 USD	2004 G Mass	2005 G Mass	2006 G Mass	2007 G Mass	2008 G Mass	2009 G Mass	2010 G Mass	Aggregate Total G Mass
Republic Of Malawi	Eastern Africa	5,325.00	25.00	0.00	138.00	0.00	524.00	27.00	0.00	714.00
Republic Of Uganda	Eastern Africa	17,015.00	70.00	0.00	0.00	50.00	0.00	530.18	2999.00	3649.18
Republic Of Zambia	Eastern Africa	16,201.00	450.00	91.00	0.00	74.00	106.00	359.71	0.00	1080.71
Republic Of Zimbabwe	Eastern Africa	7,204.00	0.00	0.00	343.00	231.00	49.00	1117.00	0.00	1740.00
Rwandese Republic	Eastern Africa	5,655.00	0.00	0.00	0.00	0.00	0.00	565.00	386.34	951.34
Seychelles	Eastern Africa	991.00	0.00	0.00	1400.00	0.00	0.00	0.00	10.04	1410.04
Somali Democratic Republic	Eastern Africa	1,071.00	0.00	40.00	0.00	0.00	0.00	0.00	0.00	40.00
United Republic Of Tanzania	Eastern Africa	22,502.00	17.00	0.00	817.00	803.00	186.00	994.00	67.00	2884.00
Angola	Middle Africa	82,470.00	42.00	0.00	1.00	47.00	68.00	0.00	0.00	158.00
Cameroon	Middle Africa	23,649.00	20.00	221.00	0.00	196.00	174.00	55.00	629.55	1295.55
Central African Republic	Middle Africa	1,984.00	0.00	0.00	0.00	0.00	0.00	266.15	0.00	266.15
Chad	Middle Africa	8,166.00	0.00	0.00	0.00	0.00	0.00	0.00	5.50	5.50
Congo	Middle Africa	10,775.00	0.00	0.00	0.00	74.00	86.00	772.00	0.00	932.00
Equatorial Guinea	Middle Africa	11,803.00	0.00	0.00	0.00	0.00	0.00	0.00	78.65	78.65
Gabon	Middle Africa	18,771.00	2329.00	100.00	0.00	382.00	43.00	4.00	280.95	3138.95
Zaire	Middle Africa	13,230.00	0.00	0.00	0.00	523.00	0.00	0.00	0.00	523.00
Algeria	Northern Africa	158,650.00	1701.00	166.00	0.00	66.00	271.00	0.00	24.45	2228.45
Egypt	Northern Africa	215,272.00	382.00	335.00	27.00	918.00	1649.00	935.98	1524.00	5770.98
Libya	Northern Africa	71,945.00	286.00	56.00	67.00	0.00	705.00	160.11	859.54	2133.65
Morocco	Northern Africa	91,542.00	2695.00	94.00	43.00	358.00	431.00	859.00	7833.20	12313.20
Sudan	Northern Africa	79,480.00	0.00	0.00	124.00	100.00	82.00	0.00	0.00	306.00
Tunisia	Northern Africa	44,252.00	0.00	0.00	50.00	0.00	3056.00	532.52	86.09	3724.61
Botswana	Southern Africa	14,857.00	2521.00	1091.00	2070.00	2562.00	402.00	345.92	784.00	9775.92
Kingdom Of Lesotho	Southern Africa	2,129.00	0.00	0.00	0.00	0.00	0.00	0.00	210.22	210.22
Kingdom Of Swaziland	Southern Africa	3,927.00	0.00	0.00	0.00	29.00	33.00	0.00	0.00	62.00
Namibia	Southern Africa	11,701.00	1232.00	1.00	60.00	152.00	41.00	0.00	0.00	1486.00
South Africa	Southern Africa	363,704.00	57897.00	48652.00	77075.00	89288.00	38887.00	39707.87	213.27	351720.14
Burkina Faso	Western Africa	8,559.00	0.00	0.00	0.00	0.00	0.00	0.00	800.00	800.00
Cote D'ivoire	Western Africa	22,780.00	1312.00	1233.00	905.00	4370.00	43.00	5961.00	3471.97	17295.97
Gambia	Western Africa	1,001.00	230.00	1718.00	6.00	0.00	0.00	0.00	0.00	1954.00
Guinea	Western Africa	4,267.00	200.00	1968.00	0.00	150.00	445559.00	67.00	74.81	448018.81
Guinea Bissau	Western Africa	817.00	0.00	0.00	0.00	0.00	4.00	0.00	0.00	4.00
Liberia	Western Africa	873.00	1625.00	45.00	16.00	3592.00	29.00	314.00	0.00	5621.00
Mali	Western Africa	9,204.00	0.00	0.00	0.00	19.00	2.00	0.00	110.00	131.00
Mauritania	Western Africa	3,913.00	0.00	0.00	0.00	14.00	0.00	0.00	0.00	14.00
Niger	Western Africa	5,549.00	3908.00	0.00	1175.00	6217.00	15.00	0.00	400.00	11715.00
Nigeria	Western Africa	196,410.00	10092.00	4213.00	5077.00	11609.00	26188.00	14219.18	31106.41	102504.59
Senegal	Western Africa	12,841.00	278.00	5326.00	3935.00	9657.00	3186.00	23768.21	1000.62	47150.83
Sierra Leone	Western Africa	2,064.00	101.00	20.00	0.00	320.00	400.00	10531.58	392.82	11765.40
Togo	Western Africa	3,162.00	0.00	1645.00	1783.00	2564.00	683.00	646.00	1081.71	8402.71
China	Eastern Asia	5,739,360.00	113694.00	161331.00	311508.00	607431.00	517252.00	409460.39	449527.20	2570203.59

		GDP as of 2010	2004	2005	2006	2007	2008	2009	2010	Aggregate
Country of origin	**Region**	**USD**	**G Mass**	**G Mass**	**G Mass**	**G Mass**	**G Mass**	**G Mass**	**G Mass**	**Total G Mass**
Hong Kong	Eastern Asia	224,459.00	16254.00	11130.00	19064.00	29553.00	51645.00	153692.81	152895.03	434233.84
Japan	Eastern Asia	5,458,870.00	70474.00	39156.00	51707.00	42419.00	62975.00	63859.51	80102.19	410692.70
Korea, Democratic	Eastern Asia	12,278.00	38.00	0.00	0.00	21.00	21.00	0.00	16.00	96.00
Korea, Republic Of	Eastern Asia	1,014,370.00	49385.00	32835.00	43968.00	137899.00	264481.00	103532.13	87865.14	719965.27
Mongolia	Eastern Asia	6,192.00	0.00	0.00	0.00	100.00	0.00	0.00	92.00	192.00
Macau	Eastern Asia	-	0.00	0.00	0.00	0.00	21.00	0.00	0.00	21.00
Taiwan	Eastern Asia	-	11013.00	938.00	3544.00	1729.00	8194.00	608.09	5679.75	31705.84
Bangladesh	South-central Asia	99,689.00	20.00	0.00	300.00	0.00	0.00	0.00	0.00	320.00
India	South-central Asia	1,722,330.00	4380.00	9765.00	6798.00	37453.00	31945.00	43437.50	72358.40	206136.90
Iran	South-central Asia	386,670.00	0.00	0.00	1203.00	124.00	34.00	0.00	455.44	1816.44
Kazakhstan	South-central Asia	146,908.00	0.00	91.00	0.00	0.00	0.00	0.00	0.00	91.00
Pakistan	South-central Asia	174,150.00	1546.00	41.00	0.00	33.00	1743.00	24.00	430.68	3817.68
Sri Lanka	South-central Asia	49,549.00	0.00	0.00	0.00	0.00	0.00	4.00	0.00	4.00
Turkmenistan	South-central Asia	23,130.00	0.00	0.00	0.00	200.00	0.00	0.00	0.00	200.00
British Indian Ocean Territory		-	0.00	0.00	0.00	1.00	0.00	0.00	0.00	1.00
Brunei Darussalam	South-eastern Asia	13,024.00	0.00	0.00	0.00	29.00	0.00	0.00	0.00	29.00
Indonesia	South-eastern Asia	707,448.00	4456.00	679.00	5695.00	4869.00	84.00	4696.00	308.48	20787.48
Malaysia	South-eastern Asia	237,797.00	25778.00	347.00	6616.00	4379.00	6392.00	454321.00	2693.67	500526.67
Philippines	South-eastern Asia	199,591.00	0.00	0.00	161.00	0.00	225.00	1956.39	80.00	2422.39
Singapore	South-eastern Asia	222,699.00	35039.00	12008.00	1572.00	11519.00	5259.00	61428.82	34306.00	161131.82
Thailand	South-eastern Asia	318,850.00	17613.00	3841.00	4889.00	4409.00	8914.00	961.46	1994.44	42621.90
Vietnam	South-eastern Asia	103,902.00	26.00	0.00	258.00	0.00	1944.00	355.51	95.61	2679.12
Azerbaijan	Western Asia	51,797.00	0.00	0.00	75.00	0.00	0.00	0.00	0.00	75.00
Bahrain	Western Asia	22,945.00	0.00	6.00	0.00	0.00	264.00	291.00	55.00	616.00
Cyprus	Western Asia	22,957.00	0.00	0.00	0.00	0.00	1788.00	482.64	132.07	2402.71
Georgia	Western Asia	11,665.00	0.00	15.00	37.00	388.00	0.00	19.00	0.00	459.00
Israel	Western Asia	217,445.00	13886.00	7278.00	8746.00	11785.00	17306.00	22845.26	10016.23	91862.49
Jordan	Western Asia	27,504.00	0.00	25.00	32.00	0.00	0.00	0.00	373.82	430.82
Kuwait	Western Asia	124,331.00	570.00	128.00	731.00	394.00	1396.00	1490.83	1039.74	5749.57
Lebanon	Western Asia	39,248.00	71137.00	30951.00	84993.00	70120.00	135399.00	88807.00	64364.12	545771.12
Oman	Western Asia	57,850.00	98.00	534.00	100.00	778.00	398.00	274.00	0.00	2182.00
Qatar	Western Asia	127,333.00	0.00	67.00	34.00	2001.00	1438.00	731.28	2262.06	6533.34
Saudi Arabia	Western Asia	434,666.00	760.00	10493.00	8241.00	5831.00	12909.00	3874.03	7845.26	49953.29
Syrian Arab Republic	Western Asia	59,834.00	885.00	0.00	240.00	0.00	0.00	0.00	0.00	1125.00
Turkey	Western Asia	734,440.00	17257.00	1843.00	32913.00	4955.00	4566.00	882.38	5345.14	67761.52
United Arab Emirates	Western Asia	297,648.00	345209.00	254216.00	286830.00	336230.00	531907.00	308171.96	325031.91	2387595.87
Bulgaria	Eastern Europe	47,702.00	0.00	7.00	330.00	0.00	0.00	1154.00	31.00	1522.00
Czech Republic	Eastern Europe	197,674.00	1169.00	0.00	159.00	312.00	115.00	361.00	444.00	2560.00
Hungary	Eastern Europe	128,629.00	63.00	0.00	80.00	0.00	781.00	0.00	147.15	1071.15
Poland	Eastern Europe	469,393.00	0.00	24.00	0.00	69.00	125.00	104.00	1120.91	1442.91
Romania	Eastern Europe	161,629.00	20.00	50.00	171.00	0.00	18.00	0.00	178.78	437.78

		GDP as of 2010	2004	2005	2006	2007	2008	2009	2010	Aggregate
Country of origin	**Region**	**USD**	**G Mass**	**G Mass**	**G Mass**	**G Mass**	**G Mass**	**G Mass**	**G Mass**	**Total G Mass**
Russian Federation	Eastern Europe	1,479,820.00	84.00	66.00	404.00	567.00	37.00	810.00	1055.14	3023.14
Slovakia	Eastern Europe	87,263.00	49.00	15.00	11.00	22.00	0.00	0.00	0.00	97.00
Ukraine	Eastern Europe	137,936.00	0.00	30.00	0.00	399.00	83.00	0.00	772.19	1284.19
Denmark	Northern Europe	309,866.00	377098.00	163195.00	66930.00	62823.00	48853.00	86962.91	119333.91	925195.82
Finland	Northern Europe	238,731.00	192.00	1961.00	6388.00	7480.00	13832.00	24223.19	12678.38	66754.57
Iceland	Northen Europe	12,574.00	0.00	0.00	0.00	486.00	0.00	8.00	0.00	494.00
Ireland	Northern Europe	206,600.00	186037.00	12309.00	35911.00	13792.00	31715.00	43304.00	18105.23	341173.23
Latvia	Northern Europe	24,014.00	0.00	0.00	15.00	79.00	0.00	45.00	92.00	231.00
Norway	Northern Europe	413,056.00	73840.00	68714.00	70831.00	86043.00	79530.00	44461.35	42983.25	466402.60
Sweden	Northern Europe	458,725.00	160630.00	18543.00	51884.00	52006.00	53182.00	25357.78	24925.13	386527.91
Bosnia & Herzegovina	Southern Europe	16,837.00	0.00	0.00	0.00	0.00	10.00	0.00	0.00	10.00
Greece	Southern Europe	301,065.00	936.00	295.00	504.00	891.00	2447.00	4338.48	4616.71	14028.19
Italy	Southern Europe	2,051,290.00	187340.00	6646378.00	141374.00	214698.00	155533.00	244995.52	213557.67	7803876.19
Malta	Southern Europe	8,163.00	27.00	0.00	0.00	0.00	234.00	0.00	0.00	261.00
Portugal	Southern Europe	228,859.00	8376.00	12.00	326.00	1703.00	1945.00	58.59	1558.96	13979.55
San Marino	Southern Europe	1,487.00	0.00	0.00	0.00	476.00	0.00	0.00	0.00	476.00
Slovenia	Southern Europe	46,906.00	0.00	0.00	0.00	0.00	0.00	7.00	0.00	7.00
Spain	Southern Europe	1,407,320.00	47227.00	106353.00	28228.00	82171.00	90137.00	55466.77	37711.18	447293.95
Gibraltar		-	0.00	0.00	0.00	0.00	0.00	4.00	0.00	4.00
Yugoslavia		-	0.00	371.00	0.00	0.00	0.00	76.00	52,995.62	53442.62
Austria	Western Europe	379,047.00	959.00	2149.00	1835.00	6922.00	5385.00	3102.59	541.88	20894.47
Belgium	Western Europe	469,347.00	411014.00	652046.00	508175.00	404571.00	360511.00	1195338.80	212217.81	3743873.61
France	Western Europe	2,556,850.00	186871.00	240434.00	252518.00	379048.00	243484.00	3041200.62	176597.63	4520153.25
Germany	Western Europe	3,280,330.00	456983.00	993647.00	360043.00	513531.00	1691775.00	346652.67	388493.12	4751124.79
Luxembourg	Western Europe	53,330.00	3.00	41.00	27.00	0.00	7.00	37.00	1.00	116.00
Netherlands	Western Europe	779,310.00	817506.00	616986.00	699537.00	759606.00	547692.00	381838.15	437910.61	4261075.76
Switzerland	Western Europe	527,920.00	79785.00	100517.00	22553.00	5304.00	102800.00	13398.18	4314.61	328671.79
United Kingdom	Western Europe	2,253,550.00	1366294.00	1730394.00	2014491.00	2264022.00	4925744.00	3001028.23	2776478.07	18078451.30
New Zealand	Oceania	141,406.00	66414.00	22358.00	16278.00	9754.00	6459.00	7287.65	2908.01	131458.66
Vanuatu	Oceania	710.00	0.00	0.00	147.00	0.00	0.00	0.00	58.00	205.00
Australia	Oceania	1,271,950.00	80647.00	8215.00	82604.00	97821.00	81949.00	57004.44	80707.30	488947.74
American Samoa	Oceania Polynesia	-	0.00	206.00	5.00	85.00	0.00	0.00	0.00	296.00
New Caledonia	Oceania-Melanesia	8,861.00	0.00	0.00	0.00	0.00	17.00	0.00	0.00	17.00
Marshall Islands	Oceania-Micronesia	116.00	0.00	6.00	0.00	0.00	0.00	0.00	0.00	6.00
Norfolk Island		-	0.00	0.00	0.00	0.00	1478.00	0.00	0.00	1478.00
	Grand Total		**7,611,097.00**	**14,216,371.00**	**7,261,491.00**	**8,555,211.00**	**16,609,341.00**	**12,314,652.93**	**7,488,528.97**	**74,014,545.90**

Source : Ghana CES (2010)

Ghana's 2010 GDP = 32,520.00 USD

Appendix E1

Soil Sampling Data

E-waste Site	Station	Site short code	Pb	Cu	Sb	Zn	As	Cd	Hg
			mg/kg						
Agbogboshie	Dismantling	AGB-STA (P1)	148.23	8.97	11.07	8.85	1.48	1.65	0.21
Agbogboshie	Dismantling	AGB-STA (P2)	180.27	7.07	19.89	11.77	3.35	2.36	0.24
Agbogboshie	Dismantling	AGB-STA (P3)	216.63	5.67	78.82	9.16	2.64	2.45	0.48
Agbogboshie	Dismantling	AGB-STA (P4)	208.97	9.4	16.33	7.06	1.44	0.83	0.49
Agbogboshie	Open Burning	AGB-STB (P1)	262.77	7.21	107.01	9.32	3.75	2.99	0.67
Agbogboshie	Open Burning	AGB-STB (P2)	260.23	7.93	114.75	13.39	2.86	7.87	0.19
Agbogboshie	Open Burning	AGB-STB (P3)	229.46	7.97	49.28	12.15	3.12	0.8	0.44
Agbogboshie	Open Burning	AGB-STB (P4)	263.43	6.87	9.41	6.83	3.81	12.88	0.13
Agbogboshie	Disposal	AGB-STC (P1)	233.53	5.11	80.33	11.77	2.79	0.33	0.41
Agbogboshie	Disposal	AGB-STC (P2)	265.03	7.69	29.49	13.11	3.71	2.75	0.44
Agbogboshie	Disposal	AGB-STC (P3)	246.97	5.79	88.52	10.91	4.12	2.12	0.51
Agbogboshie	Disposal	AGB-STC (P4)	143.72	8.76	71.37	8.41	1.59	1.29	0.25
E-waste Site	**Station**	**Site short code**	**Pb**	**Cu**	**Sb**	**Zn**	**As**	**Cd**	**Hg**
Ashaiman	Dismantling	ASH-STA (P1)	198.54	4.20	32.21	3.05	4.07	2.75	0.36
Ashaiman	Dismantling	ASH-STA (P2)	262.16	8.33	55.71	7.79	4.21	0.67	0.49
Ashaiman	Dismantling	ASH-STA (P3)	141.41	99.93	12.71	13.99	10.79	0.72	1.56
Ashaiman	Dismantling	ASH-STA (P4)	20.07	24.11	11.23	4.35	5.45	0.36	0.11
Ashaiman	Open Burning	ASH-STB (P1)	254.05	10.07	178.29	3.59	4.12	2.05	0.51
Ashaiman	Open Burning	ASH-STB (P2)	132.16	82.08	59.36	13.75	11.00	3.20	1.37
Ashaiman	Open Burning	ASH-STB (P3)	205.52	9.09	51.37	4.32	4.69	0.60	0.29
Ashaiman	Open Burning	ASH-STB (P4)	164.61	9.68	30.37	13.33	3.50	0.59	0.31
Ashaiman	Disposal	ASH-STC (P1)	51.96	14.44	12.01	11.67	7.04	0.41	0.55
Ashaiman	Disposal	ASH-STC (P2)	3.45	5.33	2.57	1.09	0.29	0.14	0.12
Ashaiman	Disposal	ASH-STC (P3)	185.90	8.75	41.57	4.12	4.33	0.71	0.25
Ashaiman	Disposal	ASH-STC (P4)	73.74	54.11	13.61	9.97	9.48	0.67	0.80
E-waste Site	**Station**	**Site short code**	**Pb**	**Cu**	**Sb**	**Zn**	**As**	**Cd**	**Hg**
Tema	Dismantling	TMA-STA (P1)	29.39	14.79	19.73	8.49	5.19	1.29	0.21
Tema	Dismantling	TMA-STA (P2)	66.33	28.07	17.00	8.95	7.41	1.01	0.05
Tema	Dismantling	TMA-STA (P3)	138.29	97.40	21.12	14.11	11.35	1.05	1.44
Tema	Dismantling	TMA-STA (P4)	71.49	48.88	13.57	9.75	8.79	0.93	0.68
Control Site	**Station**	**Site short code**	**Pb**	**Cu**	**Sb**	**Zn**	**As**	**Cd**	**Hg**
Mataheko	Control	CT - SP1	2.91	2.96	2.83	1.33	0.21	0.09	0.05
Mataheko	Control	CT - SP2	2.60	2.63	4.60	0.85	0.15	0.07	0.03
Mataheko	Control	CT - SP3	172.93	9.41	35.31	2.41	3.81	2.03	0.39
Mataheko	Control	CT - SP4	14.11	12.28	4.96	3.75	5.12	0.31	0.08

APPENDIX D2

Urine Sampling Data

Location	Subject	Region of	Current	Sex	Age	Alcohol	Smoking	E-waste	EW Exp.	Cu	Zn	Sb	Pb	As	Cd	Hg
	Code	Hometown	Residence		(Yrs)	Drinking	Habit	Activity	(Years)				mg/L			
AGB	AGB-EWW1	NR	AGB	M	15	Yes	Yes	DM+OB	6	0.748	0.128	1.804	0.108	<0.001	<0.002	<0.001
AGB	AGB-EWW2	NR	AGB	M	23	Yes	Yes	OB	3	0.832	0.16	1.456	0.336	0.008	<0.002	<0.001
AGB	AGB-EWW3	NR	AGB	M	24	No	Yes	OB	6	1.048	0.16	0.472	0.364	0.008	<0.002	<0.001
AGB	AGB-EWW4	NR	AGB	M	20	No	Yes	OB	1	0.8	0.216	0.892	0.336	0.004	<0.002	<0.001
AGB	AGB-EWW5	NR	AGB	M	14	No	Yes	OB	3	0.748	0.184	0.364	0.368	0.008	<0.002	<0.001
AGB	AGB-EWW6	UW	AGB	M	12	No	Yes	OB	2	0.868	0.192	1.204	0.288	0.004	<0.002	<0.001
AGB	AGB-EWW7	UE	AGB	M	15	No	Yes	OB	4	0.772	0.14	0.056	0.404	0.008	<0.002	<0.001
AGB	AGB-EWW8	UE	AGB	M	19	No	Yes	OB	4	0.796	0.124	0.44	0.376	0.008	<0.002	<0.001
ASH	ASH-EWW1	NR	ASH	M	20	No	No	DM+OB	3	<0.003	<0.001	0.524	0.016	0.012	<0.002	<0.001
ASH	ASH-EWW2	NR	ASH	M	22	No	No	DM+OB	6	<0.003	<0.001	0.478	0.028	0.02	<0.002	<0.001
ASH	ASH-EWW3	NR	ASH	M	20	No	yes	DM+OB	4	<0.003	<0.001	0.372	0.056	0.024	<0.002	<0.001
ASH	ASH-EWW4	NR	ASH	M	30	No	No	CL+DM	3	<0.003	<0.001	0.448	0.024	0.068	<0.002	<0.001
ASH	ASH-EWW5	NR	ASH	M	18	No	No	CL+DM	3	<0.003	<0.001	0.384	0.016	0.052	<0.002	<0.001
ASH	ASH-EWW6	NR	AGB	M	24	No	No	CL+DM	14	<0.003	<0.001	0.428	0.044	0.024	<0.002	<0.001
ASH	ASH-EWW7	NR	ASH	M	27	No	No	CL+DM	4	<0.003	<0.001	0.098	0.012	<0.001	<0.002	<0.001
ASH	ASH-EWW8	UE	ASH	M	19	No	No	CL+DM+OB	2	<0.003	<0.001	0.368	0.014	0.02	<0.002	<0.001
TEMA	TMA-EWW1	NR	TMA	M	28	No	Yes	CL+DM+OB	12	<0.003	<0.001	0.264	<0.001	0.008	<0.002	<0.001
TEMA	TMA-EWW2	NR	TMA	M	24	No	Yes	CL+DM	4	<0.003	<0.001	0.180	<0.001	0.012	<0.002	<0.001
TEMA	TMA-EWW3	NR	TMA	M	22	No	No	CL+DM	3	<0.003	<0.001	0.080	0.012	0.020	<0.002	<0.001
TEMA	TMA-EWW4	NR	TMA	M	21	No	No	CL+DM+OB	2	<0.003	<0.001	0.304	<0.001	0.020	<0.002	<0.001
TEMA	TMA-EWW5	NR	TMA	M	28	No	Yes	CL+DM	11	<0.003	<0.001	0.244	<0.001	0.012	<0.002	<0.001
TEMA	TMA-EWW6	NR	TMA	M	20	Yes	Yes	CL+DM+OB	4	<0.003	<0.001	0.068	<0.001	0.008	<0.002	<0.001
TEMA	TMA-EWW7	NR	AGB	M	27	No	Yes	CL+DM	17	<0.003	<0.001	0.040	0.016	0.016	<0.002	<0.001
TEMA	TMA-EWW8	NR	AGB	M	25	No	No	CL+DM	4	<0.003	<0.001	0.120	0.012	<0.001	<0.002	<0.001

Location	Subject Code	Region of Hometown	Current Residence	Sex	Age (Yrs)	Alcohol Drinking	Smoking Habit	E-waste Activity	EW Exp. (Years)	Cu	Zn	Sb	Pb	As	Cd	Hg
										mg/L						
MAT	MAT-CTR1	GRA	MAT	M	25	No	No	None	0	0.81	0.116	1.01	0.32	<0.001	<0.002	<0.001
MAT	MAT-CTR2	GRA	MAT	M	29	No	No	None	0	0.764	0.096	0.86	0.276	<0.001	<0.002	<0.001
MAT	MAT-CTR3	GRA	MAT	M	11	No	No	None	0	<0.003	<0.001	1.54	<0.001	<0.001	<0.002	<0.001
MAT	MAT-CTR4	GRA	MAT	F	13	No	No	None	0	<0.003	<0.001	2.072	<0.001	<0.001	0.08	<0.001
MAT	MAT-CTR5	GRA	MAT	F	52	Yes	No	None	0	<0.003	<0.001	1.956	<0.001	<0.001	<0.002	<0.001
MAT	MAT-CTR6	GRA	MAT	M	23	No	No	None	0	0.628	0.033	0.177	0.011	<0.001	<0.002	<0.001
MAT	MAT-CTR7	GRA	MAT	M	32	Yes	No	None	0	0.662	0.048	0.194	0.03	0.01	<0.002	<0.001
MAT	MAT-CTR8	GRA	MAT	M	25	No	No	None	0	0.284	0.016	<0.040	0.012	0.008	<0.002	<0.001

Source: Author's Fieldwork (2013)

NB:

AGB *- Agbogbloshie e-waste site*
ASH *- Ashaiman e-waste site*
TMA *- Tema e-waste site*
MAT *- Mataheko control site*
EWW *- Ewaste worker*
CTR *- Control*
NR *- Northern Region*
UW *- Upper West Region*
UE *- Upper East Region*
GRA *- Greater Accra Region*
EWW *Exp - Ewaste Working Experience*
M *- Male*
F *- Female*
CL *- Collection of E-waste*
DM *- Dismantling of e-waste*
OB *- Open Burning of e-waste*

Appendix F1

E-waste Imports and Management Practices in Ghana: 'A Case Study of Accra – Tema Metropolitan Area'

Questionnaire for Respondents from the Government Sector

I am a Master of Philosophy Environmental Science student of the University of Ghana, and I am presently conducting a research on Electronic Waste Imports and Management in the Accra-Tema Metropolis. You are kindly requested to participate in this study to examine the flow and handling of used electrical and electronic items / electronic waste, and the implications for environment and health in the Accra-Tema Metropolis. Your participation in this research will take about 20 minutes of your time. If you agree to take part in this research, I will be asking you questions about your personal data, the source and types of electronic equipment you deal in, how you handle them, the challenges you face in your work, and your views on how to address these challenges.

Date: ____
Name of Respondent: ____ (optional)
Gender:____
Organization: ____
Position ____(optional)
Number of years in service: _____________________________________
Contact number / Email address ______________________________________ (optional)

<u>A: Policies and legislative Framework</u>

1. Is there any existing national policy or legislation regarding the importation of (used) electrical and electronic equipment in Ghana that you are aware of?

<u>B: EEE imports Handling</u>

2. Can you please describe briefly the port procedure for the importation of electrical and electronic goods in Ghana?
3. How would you describe the quality of UEEE imports arriving at the port?
4. Are there any mechanisms in place for checking the functionality or quality monitoring of Used Electrical and Electronic Equipment (UEEE) imports in Ghana?
5. Which regulatory authorities are involved in the inspections of UEEE imports? How do they collaborate and communicate?
6. What specific role does your organisation play with regard to the importation of (U)EEE?
7. Can you please describe how inspections of UEEE imports are performed in the Tema Port, and what is done in case of detection of prohibited UEEE imports at the port?
8. Has there been any incidence of detection of prohibited UEEE imports at the Tema Port this year? What happened to the imported items and the importers?

<u>D: Challenges and Way Forward</u>

9. What would you say are the main challenges encountered by regulatory authorities/officials during monitoring / inspections of UEEE imports at the port? What suggestions would you give to address these challenges?
10. From your point of view, what measures should be put in place to effectively tackle the import flow of non-functional UEEE or e-waste in Ghana.
11. What key role(s) do you think commercial/private port actors can play with regard to the control of non-functional UEEE or e-waste in Ghana?

Appendix F2

E-waste Imports and Management Practices in Ghana: 'A Case Study of Accra – Tema Metropolitan Area'

Questionnaire for clearing agents, importers and retailers

I am a Master of Philosophy Environmental Science student of the University of Ghana, and I am presently conducting a research on Electronic Waste Imports and Management in the Accra-Tema Metropolis. You are kindly requested to participate in this study to examine the flow and handling of used electrical and electronic items / electronic waste, and the implications for environment and health in the Accra-Tema Metropolis. Your participation in this research will take about 20 minutes of your time. If you agree to take part in this research, I will be asking you questions about your personal data, the source and types of electronic equipment you deal in, how you handle them, the challenges you face in your work, and your views on how to address these challenges.

Date: ____

Name of Respondent: ____ (optional)

Gender:____

Organization: ____

Position ____(optional)

Number of working years in the company: _______________________________________

Contact number / Email address ______________________________________ (optional)

A: Policies and legislative Framework

1. Is there any existing national policy or legislation regarding the importation of (used) electrical and electronic equipment in Ghana that you are aware of?

B: EEE Imports Handling

1. What is the nature of your business?
2. What specific role does your company play with regard to the shipments / importation / handling of (U)EEE?
3. For how many years have you/ your company been in the business of handling UEEE at the port or importing UEEE in Ghana.
4. From which main countries do you/ your company often ship /import (U)EEE into Ghana? What types of UEEE do you import / handle?
5. How would you describe the nature/quality of UEEE imports that arrives at the ports.
6. Are some of the UEEE you import/handle non-functional on arrival? What do you do with them?

C: Challenges and Way Forward

7. What would you say are the main challenges confronting you / your organisation with regard to the shipments/importation/handling of UEEE?
8. From your point of view, what measures should be put in place to effectively tackle the import flow of non-functional UEEE in Ghana.
9. What key role(s) do you think private/commercial port actors can play with regard to the control of non-functional UEEE or e-waste imports in Ghana?

Appendix F3

E-waste Imports and Management Practices in Ghana: 'A Case Study of Accra – Tema Metropolitan Area'

Questionnaire for Urine Sampling Volunteers

I am a Master of Philosophy Environmental Science student of the University of Ghana, and I am presently conducting a research on Electronic Waste Imports and Management in the Accra-Tema Metropolis. You are kindly requested to participate in this study to examine the flow and handling of used electronic items/electronic waste, and the implications for environment and health in the Accra-Tema Metropolis. Your participation in this research will take about 20 minutes of your time. If you agree to take part in this research, I will be asking you questions about your personal data, the source and types of electronic equipment you deal in, how you handle them, the challenges you face in your work, and your views on how to address these challenges. In addition, if you are directly involved in the recycling of electronic waste, I will be collecting your urine for laboratory analysis, and ask you about your smoking and alcohol drinking habits.

Date: ………................................

A: Background Characteristics

1. Gender: male ☐ female ☐
2. Age:____
3. Region of Hometown: ______________________________
4. Current Residence ________________________________
5. Occupation: ____________________________________

B: E-waste Handling Activities:

6. For how long (years) have you been in the e-waste business?
7. Which e-waste processing operation(s) do you engage in? (e.g. collection, dismantling, open burning)

B: Smoking habits and Alcohol Consumption

8. Do you smoke?
9. Do you drink alcohol?

Thank you.

Statistical Data

Statistical analysis for soil heavy metals concentrations between Agbogbloshie and Ashaiman dismantling stations

One-way

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Pb	Between Groups	2175.596	1	2175.596	0.377	0.562
	Within Groups	34668.477	6	5778.079		
	Total	36844.073	7			
Cu	Between Groups	1390.224	1	1390.224	1.390	0.283
	Within Groups	6000.516	6	1000.086		
	Total	7390.740	7			
Sb	Between Groups	25.417	1	25.417	0.035	0.857
	Within Groups	4322.057	6	720.343		
	Total	4347.474	7			
Zn	Between Groups	7.349	1	7.349	0.531	0.494
	Within Groups	83.009	6	13.835		
	Total	90.358	7			
As	Between Groups	30.457	1	30.457	5.592	0.056
	Within Groups	32.681	6	5.447		
	Total	63.138	7			
Cd	Between Groups	0.978	1	0.978	1.110	0.333
	Within Groups	5.286	6	0.881		
	Total	6.264	7			
Hg	Between Groups	0.151	1	0.151	0.699	0.435
	Within Groups	1.298	6	0.216		
	Total	1.450	7			

Statistical analysis for soil heavy metals concentrations between Agbogbloshie and Tema e-waste dismantling stations

One -way

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Pb	Between Groups	25155.350	1	25155.350	16.648	**0.007**
	Within Groups	9065.865	6	1510.978		
	Total	34221.215	7			
Cu	Between Groups	3121.236	1	3121.236	4.743	0.072
	Within Groups	3948.343	6	658.057		
	Total	7069.579	7			
Sb	Between Groups	373.808	1	373.808	0.734	0.424
	Within Groups	3054.736	6	509.123		
	Total	3428.543	7			
Zn	Between Groups	2.478	1	2.478	0.477	0.516
	Within Groups	31.197	6	5.200		
	Total	33.675	7			
As	Between Groups	70.939	1	70.939	18.874	**0.005**
	Within Groups	22.552	6	3.759		
	Total	93.491	7			
Cd	Between Groups	1.123	1	1.123	3.806	0.099
	Within Groups	1.769	6	0.295		
	Total	2.892	7			
Hg	Between Groups	0.117	1	0.117	0.570	0.479
	Within Groups	1.228	6	0.205		
	Total	1.345	7			

Statistical analysis for soil heavy metals concentrations between Ashaiman and Tema e-waste dismantling Stations

One-way

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Pb	Between Groups	12535.288	1	12535.288	1.983	0.209
	Within Groups	37934.899	6	6322.483		
	Total	50470.187	7			
Cu	Between Groups	345.302	1	345.302	0.209	0.664
	Within Groups	9930.866	6	1655.144		
	Total	10276.168	7			
Sb	Between Groups	204.279	1	204.279	0.919	0.375
	Within Groups	1333.822	6	222.304		
	Total	1538.101	7			
Zn	Between Groups	18.361	1	18.361	1.203	0.315
	Within Groups	91.59	6	15.265		
	Total	109.951	7			
As	Between Groups	8.432	1	8.432	1.012	0.353
	Within Groups	50.014	6	8.336		
	Total	58.446	7			
Cd	Between Groups	0.005	1	0.005	0.008	0.931
	Within Groups	3.661	6	0.61		
	Total	3.666	7			
Hg	Between Groups	0.002	1	0.002	0.006	0.943
	Within Groups	2.391	6	0.398		
	Total	2.393	7			

Statistical analysis for soil heavy metals concentrations between Agbogbloshie and Ashaiman open burning stations

One-way

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Pb	Between Groups	8420.951	1	8420.951	5.529	0.057
	Within Groups	9137.654	6	1522.942		
	Total	17558.605	7			
Cu	Between Groups	818.854	1	818.854	1.247	0.307
	Within Groups	3939.733	6	656.622		
	Total	4758.588	7			
Sb	Between Groups	189.56	1	189.56	0.055	0.823
	Within Groups	20841.841	6	3473.64		
	Total	21031.401	7			
Zn	Between Groups	5.629	1	5.629	0.286	0.612
	Within Groups	118.105	6	19.684		
	Total	123.734	7			
As	Between Groups	11.938	1	11.938	1.934	0.214
	Within Groups	37.032	6	6.172		
	Total	48.97	7			
Cd	Between Groups	40.922	1	40.922	2.679	0.153
	Within Groups	91.637	6	15.273		
	Total	132.558	7			
Hg	Between Groups	0.138	1	0.138	0.853	0.391
	Within Groups	0.969	6	0.162		
	Total	1.107	7			

Statistical analysis for soil heavy metals concentrations between Agbogbloshie and Ashaiman e-waste disposal stations

One-way

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Pb	Between Groups	41213.32	1	41213.32	9.286	**0.023**
	Within Groups	26629.75	6	4438.292		
	Total	67843.07	7			
Cu	Between Groups	381.818	1	381.818	1.485	0.269
	Within Groups	1542.834	6	257.139		
	Total	1924.652	7			
Sb	Between Groups	4997.254	1	4997.254	10.29	**0.018**
	Within Groups	2913.849	6	485.641		
	Total	7911.103	7			
Zn	Between Groups	37.616	1	37.616	2.648	0.155
	Within Groups	85.22	6	14.203		
	Total	122.837	7			
As	Between Groups	9.982	1	9.982	1.191	0.317
	Within Groups	50.278	6	8.38		
	Total	60.26	7			
Cd	Between Groups	2.603	1	2.603	4.455	0.079
	Within Groups	3.506	6	0.584		
	Total	6.109	7			
Hg	Between Groups	0.002	1	0.002	0.029	0.871
	Within Groups	0.314	6	0.052		
	Total	0.316	7			

Statistical analysis for soil heavy metals concentrations between Agbogbloshie dismantling station and Control site

One-way

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Pb	Between Groups	39418.39	1	39418.39	9.958	**0.020**
	Within Groups	23750.366	6	3958.394		
	Total	63168.756	7			
Cu	Between Groups	1.834	1	1.834	0.141	0.720
	Within Groups	78.014	6	13.002		
	Total	79.848	7			
Sb	Between Groups	768.67	1	768.67	1.229	0.310
	Within Groups	3753.098	6	625.516		
	Total	4521.768	7			
Zn	Between Groups	101.485	1	101.485	37.451	**0.001**
	Within Groups	16.259	6	2.71		
	Total	117.744	7			
As	Between Groups	0.018	1	0.018	0.005	0.946
	Within Groups	21.84	6	3.64		
	Total	21.858	7			
Cd	Between Groups	2.876	1	2.876	3.96	0.094
	Within Groups	4.358	6	0.726		
	Total	7.234	7			
Hg	Between Groups	0.095	1	0.095	3.743	0.101
	Within Groups	0.153	6	0.025		
	Total	0.248	7			

Statistical analysis for soil heavy metals concentrations between Ashaiman Dismantling e-waste station and Control Site

One-way

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Pb	Between Groups	23072.81	1	23072.81	2.631	0.156
	Within Groups	52619.4	6	8769.9		
	Total	75692.21	7			
Cu	Between Groups	1493.055	1	1493.055	1.478	0.270
	Within Groups	6060.536	6	1010.089		
	Total	7553.591	7			
Sb	Between Groups	514.537	1	514.537	1.519	0.264
	Within Groups	2032.184	6	338.697		
	Total	2546.722	7			
Zn	Between Groups	54.216	1	54.216	4.244	0.085
	Within Groups	76.652	6	12.775		
	Total	130.868	7			
As	Between Groups	28.98	1	28.98	3.527	0.109
	Within Groups	49.302	6	8.217		
	Total	78.282	7			
Cd	Between Groups	0.5	1	0.5	0.48	0.514
	Within Groups	6.249	6	1.042		
	Total	6.749	7			
Hg	Between Groups	0.487	1	0.487	2.221	0.187
	Within Groups	1.315	6	0.219		
	Total	1.802	7			

Statistical analysis for soil heavy metals concentrations between Tema e-waste dismantling site and Control Site

One-way

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Pb	Between Groups	1594.905	1	1594.905	0.354	0.573
	Within Groups	27016.789	6	4502.798		
	Total	28611.694	7			
Cu	Between Groups	3274.4	1	3274.4	4.901	0.069
	Within Groups	4008.364	6	668.061		
	Total	7282.763	7			
Sb	Between Groups	70.405	1	70.405	0.552	0.485
	Within Groups	764.863	6	127.477		
	Total	835.268	7			
Zn	Between Groups	135.679	1	135.679	32.773	**0.001**
	Within Groups	24.84	6	4.14		
	Total	160.518	7			
As	Between Groups	68.676	1	68.676	10.519	**0.018**
	Within Groups	39.173	6	6.529		
	Total	107.849	7			
Cd	Between Groups	0.405	1	0.405	0.889	0.382
	Within Groups	2.732	6	0.455		
	Total	3.137	7			
Hg	Between Groups	0.423	1	0.423	2.039	0.203
	Within Groups	1.245	6	0.208		
	Total	1.668	7			

Statistical analysis for soil heavy metals concentrations between Agbogbloshie open burning station and control site

One-way

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Pb	Between Groups	84737.692	1	84737.692	23.476	**0.003**
	Within Groups	21657.504	6	3609.584		
	Total	106395.196	7			
Cu	Between Groups	0.912	1	0.912	0.078	0.789
	Within Groups	69.904	6	11.651		
	Total	70.816	7			
Sb	Between Groups	6772.028	1	6772.028	4.953	0.068
	Within Groups	8204.331	6	1367.388		
	Total	14976.358	7			
Zn	Between Groups	138.974	1	138.974	27.018	**0.002**
	Within Groups	30.863	6	5.144		
	Total	169.837	7			
As	Between Groups	2.255	1	2.255	0.68	0.441
	Within Groups	19.89	6	3.315		
	Total	22.145	7			
Cd	Between Groups	60.757	1	60.757	4.072	0.090
	Within Groups	89.519	6	14.92		
	Total	150.276	7			
Hg	Between Groups	0.098	1	0.098	2.175	0.191
	Within Groups	0.269	6	0.045		
	Total	0.367	7			

Statistical analysis for soil heavy metals concentrations between Ashaiman e-waste open burning station and control site

One-way

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Pb	Between Groups	39733.109	1	39733.109	8.17	**0.029**
	Within Groups	29181.44	6	4863.573		
	Total	68914.548	7			
Cu	Between Groups	874.413	1	874.413	1.309	0.296
	Within Groups	4007.864	6	667.977		
	Total	4882.277	7			
Sb	Between Groups	9227.603	1	9227.603	3.926	0.095
	Within Groups	14100.735	6	2350.122		
	Total	23328.338	7			
Zn	Between Groups	88.662	1	88.662	5.476	0.058
	Within Groups	97.143	6	16.191		
	Total	185.806	7			
As	Between Groups	24.569	1	24.569	2.651	0.155
	Within Groups	55.603	6	9.267		
	Total	80.171	7			
Cd	Between Groups	1.954	1	1.954	1.576	0.256
	Within Groups	7.438	6	1.24		
	Total	9.392	7			
Hg	Between Groups	0.467	1	0.467	3.222	0.123
	Within Groups	0.87	6	0.145		
	Total	1.337	7			

Statistical analysis for soil heavy metals concentrations between Agbogbloshie e-waste disposal station and control site

One-way

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Pb	Between Groups	60675.213	1	60675.213	12.305	**0.013**
	Within Groups	29586.035	6	4931.006		
	Total	90261.248	7			
Cu	Between Groups	0.001	1	0.001	0	0.995
	Within Groups	77.521	6	12.92		
	Total	77.522	7			
Sb	Between Groups	6161.491	1	6161.491	13.214	**0.011**
	Within Groups	2797.778	6	466.296		
	Total	8959.269	7			
Zn	Between Groups	160.685	1	160.685	57.724	**0.000**
	Within Groups	16.702	6	2.784		
	Total	177.386	7			
As	Between Groups	1.064	1	1.064	0.277	0.617
	Within Groups	23.01	6	3.835		
	Total	24.074	7			
Cd	Between Groups	1.997	1	1.997	2.01	0.206
	Within Groups	5.96	6	0.993		
	Total	7.957	7			
Hg	Between Groups	0.141	1	0.141	7.007	**0.038**
	Within Groups	0.121	6	0.02		
	Total	0.262	7			

Statistical analysis for soil heavy metals concentrations between Ashaiman e-waste disposal station and control site

One-way

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Pb	Between Groups	1875.994	1	1875.994	0.291	0.609
	Within Groups	38745.004	6	6457.501		
	Total	40620.999	7			
Cu	Between Groups	382.795	1	382.795	1.432	0.276
	Within Groups	1603.347	6	267.224		
	Total	1986.142	7			
Sb	Between Groups	60.901	1	60.901	0.231	0.648
	Within Groups	1579.296	6	263.216		
	Total	1640.197	7			
Zn	Between Groups	42.81	1	42.81	3.275	0.120
	Within Groups	78.42	6	13.07		
	Total	121.23	7			
As	Between Groups	17.562	1	17.562	1.603	0.252
	Within Groups	65.729	6	10.955		
	Total	83.29	7			
Cd	Between Groups	0.04	1	0.04	0.084	0.782
	Within Groups	2.867	6	0.478		
	Total	2.907	7			
Hg	Between Groups	0.172	1	0.172	2.848	0.142
	Within Groups	0.363	6	0.06		
	Total	0.535	7			

Statistical Analysis for urinary heavy metals levels between e-waste workers and control group

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ONEWAY Pb Cu Sb Zn As Cd Hg BY Group_Location_code
  /MISSING ANALYSIS

  /POSTHOC=TUKEY ALPHA(0.05).
```

Oneway

Warnings

There are fewer than two groups for dependent variable Hg. No statistics are computed.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Pb	Between Groups	0.512	3	0.171	25.157	**0.000**
	Within Groups	0.190	28	0.007		
	Total	0.701	31			
Cu	Between Groups	3.713	3	1.238	35.414	**0.000**
	Within Groups	0.979	28	0.035		
	Total	4.691	31			
Sb	Between Groups	3.482	3	1.161	4.377	**0.012**
	Within Groups	7.425	28	0.265		
	Total	10.907	31			
Zn	Between Groups	0.142	3	0.047	61.351	**0.000**
	Within Groups	0.022	28	0.001		
	Total	0.164	31			
As	Between Groups	0.003	3	0.001	7.134	**0.001**
	Within Groups	0.004	28	0		
	Total	0.007	31			
Cd	Between Groups	0.000	3	0	1	0.407
	Within Groups	0.001	28	0		
	Total	0.002	31			

Statistical Analysis for urinary heavy metals levels between e-waste workers and control group

Post Hoc Tests

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Group code	(J) Group code	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Pb	AGB-EWW	ASH-EWW	.2962500*	.0411661	.000	.183854	.408646
		TMA-EWW	.3171875*	.0411661	.000	.204791	.429584
		MAT-CTR	.2411875*	.0411661	.000	.128791	.353584
	ASH-EWW	AGB-EWW	-.2962500*	.0411661	.000	-.408646	-.183854
		TMA-EWW	.0209375	.0411661	.956	-.091459	.133334
		MAT-CTR	-.0550625	.0411661	.548	-.167459	.057334
	TMA-EWW	AGB-EWW	-.3171875*	.0411661	.000	-.429584	-.204791
		ASH-EWW	-.0209375	.0411661	.956	-.133334	.091459
		MAT-CTR	-.0760000	.0411661	.274	-.188396	.036396
	MAT-CTR	AGB-EWW	-.2411875*	.0411661	.000	-.353584	-.128791
		ASH-EWW	.0550625	.0411661	.548	-.057334	.167459
		TMA-EWW	.0760000	.0411661	.274	-.036396	.188396
Cu	AGB-EWW	ASH-EWW	.8250000*	.0934721	.000	.569792	1.080208
		TMA-EWW	.8250000*	.0934721	.000	.569792	1.080208
		MAT-CTR	.4324375*	.0934721	.000	.177230	.687645
	ASH-EWW	AGB-EWW	-.8250000*	.0934721	.000	-1.080208	-.569792
		TMA-EWW	.0000000	.0934721	1.000	-.255208	.255208
		MAT-CTR	-.3925625*	.0934721	.001	-.647770	-.137355
	TMA-EWW	AGB-EWW	-.8250000*	.0934721	.000	-1.080208	-.569792
		ASH-EWW	.0000000	.0934721	1.000	-.255208	.255208
		MAT-CTR	-.3925625*	.0934721	.001	-.647770	-.137355
	MAT-CTR	AGB-EWW	-.4324375*	.0934721	.000	-.687645	-.177230
		ASH-EWW	.3925625*	.0934721	.001	.137355	.647770
		TMA-EWW	.3925625*	.0934721	.001	.137355	.647770
Sb	AGB-EWW	ASH-EWW	.4485000	.2574774	.322	-.254494	1.151494
		TMA-EWW	.6735000	.2574774	.064	-.029494	1.376494
		MAT-CTR	-.1426250	.2574774	.945	-.845619	.560369
	ASH-EWW	AGB-EWW	-.4485000	.2574774	.322	-1.151494	.254494
		TMA-EWW	.2250000	.2574774	.818	-.477994	.927994
		MAT-CTR	-.5911250	.2574774	.123	-1.294119	.111869
	TMA-EWW	AGB-EWW	-.6735000	.2574774	.064	-1.376494	.029494
		ASH-EWW	-.2250000	.2574774	.818	-.927994	.477994
		MAT-CTR	-.8161250*	.2574774	.018	-1.519119	-.113131
	MAT-CTR	AGB-EWW	.1426250	.2574774	.945	-.560369	.845619
		ASH-EWW	.5911250	.2574774	.123	-.111869	1.294119
		TMA-EWW	.8161250*	.2574774	.018	.113131	1.519119
Zn	AGB-EWW	ASH-EWW	.1625000*	.0139048	.000	.124536	.200464
		TMA-EWW	.1625000*	.0139048	.000	.124536	.200464
		MAT-CTR	.1241875*	.0139048	.000	.086223	.162152
	ASH-EWW	AGB-EWW	-.1625000*	.0139048	.000	-.200464	-.124536
		TMA-EWW	.0000000	.0139048	1.000	-.037964	.037964
		MAT-CTR	-.0383125*	.0139048	.047	-.076277	-.000348
	TMA-EWW	AGB-EWW	-.1625000*	.0139048	.000	-.200464	-.124536
		ASH-EWW	.0000000	.0139048	1.000	-.037964	.037964
		MAT-CTR	-.0383125*	.0139048	.047	-.076277	-.000348
	MAT-CTR	AGB-EWW	-.1241875*	.0139048	.000	-.162152	-.086223
		ASH-EWW	.0383125*	.0139048	.047	.000348	.076277
		TMA-EWW	.0383125*	.0139048	.047	.000348	.076277
As	AGB-EWW	ASH-EWW	-.0215000*	.0058428	.005	-.037453	-.005547
		TMA-EWW	-.0060000	.0058428	.735	-.021953	.009953
		MAT-CTR	.0034375	.0058428	.935	-.012515	.019390
	ASH-EWW	AGB-EWW	.0215000*	.0058428	.005	.005547	.037453
		TMA-EWW	.0155000	.0058428	.059	-.000453	.031453
		MAT-CTR	.0249375*	.0058428	.001	.008985	.040890
	TMA-EWW	AGB-EWW	.0060000	.0058428	.735	-.009953	.021953
		ASH-EWW	-.0155000	.0058428	.059	-.031453	.000453
		MAT-CTR	.0094375	.0058428	.387	-.006515	.025390
	MAT-CTR	AGB-EWW	-.0034375	.0058428	.935	-.019390	.012515
		ASH-EWW	-.0249375*	.0058428	.001	-.040890	-.008985
		TMA-EWW	-.0094375	.0058428	.387	-.025390	.006515
Cd	AGB-EWW	ASH-EWW	.0000000	.0035355	1.000	-.009653	.009653
		TMA-EWW	.0000000	.0035355	1.000	-.009653	.009653
		MAT-CTR	-.0050000	.0035355	.501	-.014653	.004653
	ASH-EWW	AGB-EWW	.0000000	.0035355	1.000	-.009653	.009653
		TMA-EWW	.0000000	.0035355	1.000	-.009653	.009653
		MAT-CTR	-.0050000	.0035355	.501	-.014653	.004653
	TMA-EWW	AGB-EWW	.0000000	.0035355	1.000	-.009653	.009653
		ASH-EWW	.0000000	.0035355	1.000	-.009653	.009653
		MAT-CTR	-.0050000	.0035355	.501	-.014653	.004653
	MAT-CTR	AGB-EWW	.0050000	.0035355	.501	-.004653	.014653
		ASH-EWW	.0050000	.0035355	.501	-.004653	.014653
		TMA-EWW	.0050000	.0035355	.501	-.004653	.014653

*. The mean difference is significant at the 0.05 level.