

**SCHOOL OF PUBLIC HEALTH  
COLLEGE OF HEALTH SCIENCES  
UNIVERSITY OF GHANA**

**COMPARATIVE ANALYSIS OF CARDIO-RESPIRATORY  
FUNCTION AMONG E-WASTE WORKERS AND PERMANENT  
RESIDENTS AT AGBOGBLOSHIE, ACCRA**

**BY**

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## DECLARATION

I, Francis Agyen Frimpong, hereby declare that apart from references to other people's works which have been duly acknowledged, this thesis is as a result of my own research undertaken under the supervision of Dr. John Arko-Mensah and Prof. Julius Fobil, and that this dissertation, either in whole or in part has not been presented elsewhere for another degree.

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## **DEDICATION**

Any crown, I've ever won I lay it down, Any praise, I've ever gained, I give it all to you,  
Indeed, nothing in this world can compare... To God Almighty for his hand that sustains  
my life every bit of a second.

Secondly, to my dear wife, Dufie... And to my sons on divine assignment, Edwin and Ellis.

The Lord uphold you by His right hand and give you grace for lives well lived. Amen.

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## ABSTRACT

**Introduction:** Electronic waste (E-waste) dumping and recycling has increased significantly over the past 10 – 15 years in Ghana. The processes used in recycling however, results in the release of several toxic substances including heavy metals and toxic fumes which can have direct human health implications. Though most studies have focused on health effects due to occupational exposure to air pollutants, the direct impacts on the cardio-respiratory health of both e-waste workers and nearby populations have not been investigated sufficiently.

**Objective:** The primary objective of this study was to assess the cardio-respiratory functions of e-waste workers and permanent residents at Agbogbloshie.

**Methods:** An analytical cross-sectional study was conducted from May to July 2018 at Agbogbloshie among e-waste workers and permanent residents. A questionnaire was used to collect socio-demographic and self-reported respiratory symptoms data from respondents. Cardio-respiratory function was assessed by measuring participants' oxygen saturation, blood pressure and lung function (by spirometry). Student t-test and Pearson Chi-square were used to compare means and proportions of cardio-respiratory function indices among e-waste workers and permanent residents and a 95% confidence interval ( $p < 0.05$ ) was used to test the significance level. Regression analysis was used to determine relationships between independent variables and cardio-respiratory function parameters.

**Results:** The mean ages of e-waste workers and permanent residents were  $25 \pm 7$  years and  $29 \pm 9$  years respectively. Respiratory symptoms were higher among e-waste workers compared to the permanent residents. Excessive phlegm production was the commonest

symptom among e-waste workers (84% vs. 62%) whereas sneezing was the commonest symptom reported by permanent residents (80% vs. 74%). There was however, no significant difference in cardio-respiratory function among e-waste workers and permanent residents.

**Conclusion:** There was no significant difference in cardio-respiratory function among e-waste workers and permanent residents.

**Key words:** E-waste, cardio-respiratory function, lung function, residents

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## LIST OF ABBREVIATIONS

<b>Abbreviations</b>	<b>Meaning</b>
BFR	Brominated flame retardants
EEE	Electrical and electronic equipment
E-waste	Electronic waste
PAH	Polycyclic aromatic hydrocarbons
PBB	Polybrominated biphenyls
PBDE	Polybrominated diphenyl ethers
PCB	Polychlorinated biphenyls
POP	Persistent organic pollutants
WEEE	Waste electrical and electronic equipment
FEV	Forced Expiratory Volume
FVC	Forced Vital Capacity
BP	Blood pressure
PM	Particulate matter

## DEFINITION OF TERMS

<b>Term</b>	<b>Working Definitions</b>
E-waste	Electrical and electronic equipment at the end of their useful life
Cardio-respiratory function	The efficiency of the heart in relation to the body's entire breathing mechanism
Forced Expiratory Volume <sub>1</sub>	The amount of air that can be forcibly exhaled from the lungs in the first second of a forced exhalation
Forced Vital Capacity	The total volume of air that can be exhaled forcefully from total lung volume

## **CHAPTER ONE**

### **1.0 INTRODUCTION**

#### **1.1 Background**

Environmental pollution is known to directly impact on human health, and exposure to toxic chemicals from end of use electrical and electronic equipment poses a new health threat to the global community (Lundgren, 2012; Heacock et al., 2016).

E-waste products are made of complex amalgams of plastics and chemicals, most of which can render damaging effects to people and the environment, especially in underdeveloped countries where these products are dismantled and recycled manually (Leung, Duzgoren-Aydin, Cheung, & Wong, 2008). Some activities of e-waste workers are not geared towards retrieval and may simply involve open-air burning of unwanted e-waste products. Workers who dismantle and burn e-waste to recover precious metals and other constituents risk being exposed to hazardous substances such as polycyclic aromatic hydrocarbons (PAHs), heavy metals and inorganic acids which have an increased risk for debilitating and long-term health effects (Robinson, 2009). Even though people working in the e-waste industry may not be ignorant about the quite obvious health risks associated with their crude practices, they often show no regard for these dangers because of the income they will earn (Hirsch, 2013; Owusu-sekyere, 2014).

Pollutants from e-waste activities impact negatively on ecological health and expose both workers and nearby residential populations to noxious chemicals through inhalation, ingestion of contaminated food and dermal contact. Once absorbed, these toxic organic

chemicals are deposited in adipose tissues, leading to their bioaccumulation and burdening the body with persistent toxic substances.

Air pollutants usually comprise a composite of compounds including ozone (O<sub>3</sub>), carbon monoxide (CO), sulfur dioxide (SO<sub>2</sub>), nitrogen oxides (NO<sub>x</sub>), liquids and particulate matter (PM) (Sun, Hong, & Wold, 2010). Evidence from epidemiological studies has implicated exposure to air pollutants, specifically particulate matter, as a major risk factor having grave consequences on human health (Brook et al., 2004; Mills et al., 2009; Simkhovich, Kleinman, & Kloner, 2008). Particulate matter (PM) is categorized into coarse, fine and ultrafine particles depending on their sizes (aerodynamic diameter). Ultrafine particles for example, can travel farther into the alveoli of the lungs and possibly enter into blood circulation. Several scientific studies have established an association between PM exposure and diverse health complications such as aggravated asthma, reduced lung function, airway irritation, chronic coughs, difficulty in breathing, non-fatal heart attacks, irregular heartbeat and early death in lung cancer and patients with coronary disease (Franck, Odeh, Wiedensohler, Wehner, & Herbarth, 2011b; USEPA, 2016).

In Ghana, the Agbogbloshie area, which is a notorious hub for the informal processing and dumping of e-waste, provides a typical scenario of how e-waste pollution can invade the homes and lives of virtually all residents. This is attributed to the existing overlap between commercial, industrial and residential zones (Heacock et al., 2016). Studies have revealed that the environment (ambient air, water and surface soil) at Agbogbloshie is grossly contaminated with heavy metals such as mercury and persistent organic pollutants like organochlorine pesticides and polychlorinated biphenyls (PCBs) (Amfo-otu, Bentum, &

Omari, 2013; Labunska, Santillo, Johnston, & Brigden, 2008; Otsuka, Itai, Asante, Muto, & Tanabe, 2012).

Cumulative exposures are very likely to be high in places where informal recycling sites have ran for several years (Chen, Dietrich, Huo, & Ho, 2011). For instance, almost twice the maximum permissible exposure limits (doses) of lead, cadmium, and copper were discovered in rice and dust samples taken from homes near e-waste sites (Zheng et al., 2013). People living or working at these sites are also exposed to dust particles through inhalation, oral intake and skin contact, which may contain hazardous amounts of heavy metals (Leung, Duzgoren-Aydin, Cheung, & Wong, 2008). Again, with adequate ventilation, particles from outdoors can percolate the indoor environment and their inhalation may trigger airway inflammation, resulting in the exacerbation of respiratory and allergic diseases such as asthma (Leung et al., 2002).

Previous studies have reported associations between atmospheric pollution and decreased cardio-respiratory function, increased pulmonary and cardiovascular disease as well as hospital admission and death rates (Liu et al., 2009; Bjure, Soderholm, & Widimsky, 1964; Oftedal et al., 2008). Both acute and chronic exposures to high concentrations of outdoor air pollutants have been linked to increased deaths and hospital admissions owing to cardiovascular and pulmonary diseases (Frank, Kelly & Fussell, 2015).

## 1.2 Problem Statement

Electronic waste dumping and recycling has increased significantly over the past 10-15 years in Ghana. In the spate of modern technological advancement, the craze for trendy, highly sophisticated and efficient technology has resulted in old-fashioned electronic devices becoming antiquated and these are dumped in substantial amounts in several parts of the world. Currently, one of the major challenges with used electronic products is that the e-waste bred from advanced economies are continuously exported to lower or middle-income economies for recycling. One motivating factor is that, the labour cost of recycling in these developing countries is less compared to what would be required to recycle or dispose of the e-waste in their home countries. It has been observed that approximately 70-80% of e-waste is exported to countries within Africa and Asia (Leung, Cai, & Wong, 2006).

Many of these countries lack stringent policies and law enforcement in relation to e-waste recycling or disposal, and thus, the dismantling and burning of the e-waste is often performed manually and usually by or around children (Sepúlveda et al., 2010). Although processes used in recycling results in the release of several toxic substances including heavy metals, polychlorinated biphenyls (PCBs) and toxic fumes, the quest to make a living has allowed this sector to rather blossom, resulting in continuous pollution of the environment with toxicants (Caravanos, Clark, Fuller, & Lambertson, 2011). Some studies have associated exposure to heavy metals and dioxins for example, with an increased incidence of chronic diseases including type 2 diabetes, hypertension and other cardiovascular diseases, later in life. These toxic substances can adhere to particulate

matter (PM) in the ambient air and travel long distances away from their emission sources and hence, exposing residents nearby.

Safety concerns arise because air pollution poses a major environmental risk to health and globally, it is estimated to cause more than two million premature deaths each year (WHO, 2005). Evidence of ill-health effects coupled with the growing number of e-waste sites therefore, makes protecting both humans and the environment from e-waste contamination, a compounding challenge (Heacock et al., 2016).

Most studies on informal e-waste handling and recycling have focused primarily on environmental pollution or health effects due to occupational exposure on e-waste workers. However, these toxic substances could have direct health implications not only for e-waste workers but other members of the community. This study therefore sought to assess cardio-respiratory function indices among e-waste workers and permanent residents at Agbogbloshie and also to find out the possible impacts of pollution on their cardio-respiratory health.

### **1.3 Conceptual framework**

The conceptual framework in Figure 1 outlines the mechanisms involved in e-waste recycling leading to the release of harmful substances which can affect human health. The manual/informal recycling of e-waste results in the release of toxic substances into the environment via air, soil, ground and surface water. Inhalation is the main route of exposure among the e-waste workers and permanent residents. When these toxic substances are inhaled into the lungs, they may generate inflammatory reactions resulting in respiratory symptoms and diseases. Exposure may also occur through ingestion of contaminated food and water. Dermal exposure may occur through contaminated clothing and direct deposits onto the skin. Again, absorption and distribution through circulation can seriously impact on cardiovascular health.

Variables such as age, smoking, environmental tobacco smoke (passive smoking), indoor cooking and type of fuel used in cooking, petrochemical emissions and dust particles can also affect cardio-respiratory function.

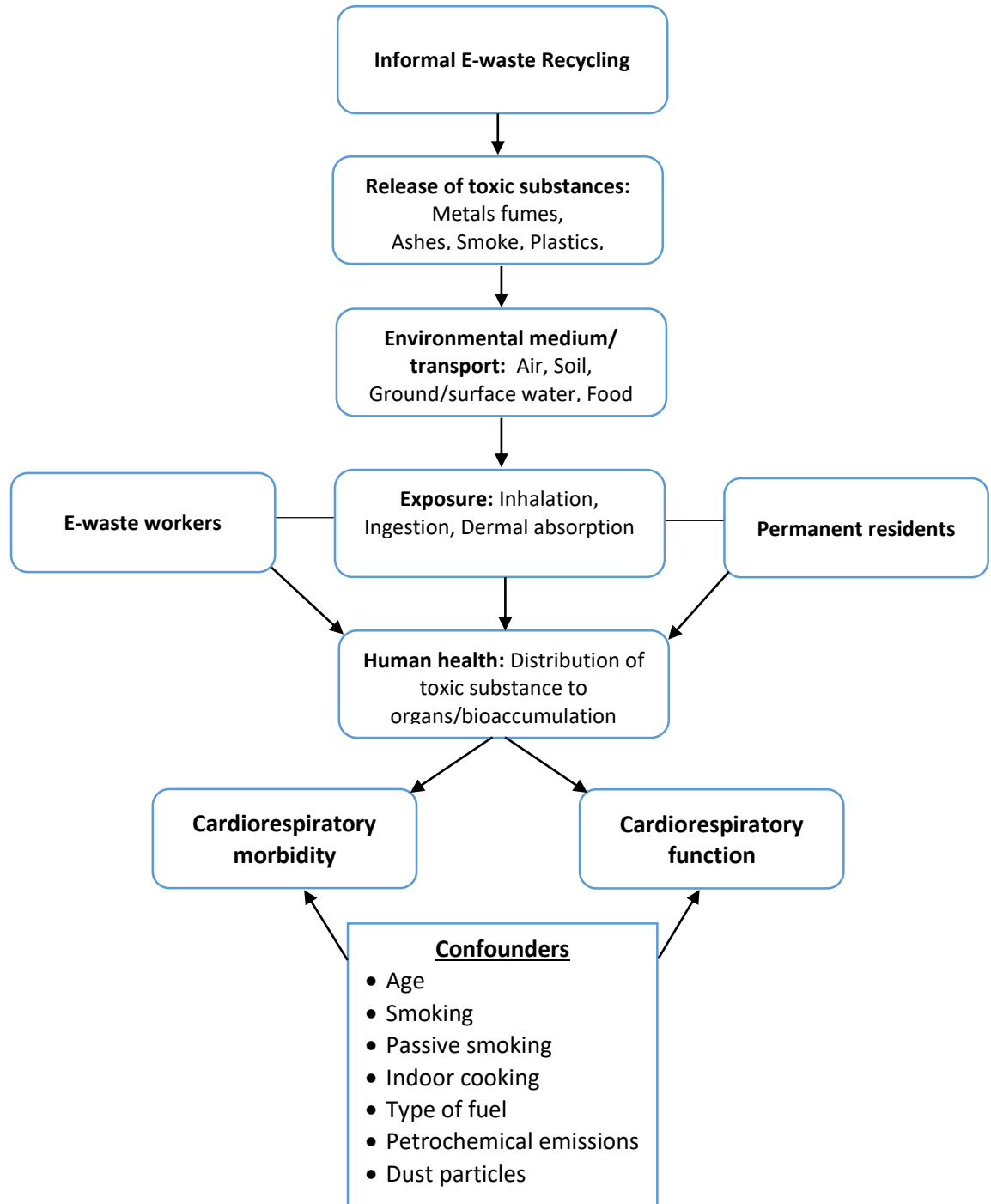


Figure 1: Conceptual framework

#### **1.4 Justification**

E-waste disposal and recycling activities are currently not being regulated by any law in Ghana. This study is therefore necessitated by the need for data on the potential health hazards associated with e-waste recycling and their impact on society, especially people living around e-waste sites.

Accurate data on exposure to air pollutants and their associated human health risks provide such key information to the legislature or governments as well as other health and development partners. Such evidence is critical to the monitoring, implementation and evaluation of policies that help to confront air pollution as well as protect human health.

Several e-waste sites are operating in Ghana with significant levels of pollution of the environment. However, the direct impact of e-waste exposure on the cardio-respiratory health of both e-waste workers and nearby populations have not been investigated sufficiently. This study will help identify the potential health risk posed by e-waste recycling activities on e-waste workers and nearby communities. Data obtained from this study will add to existing knowledge and also help develop policies to protect workers and communities from e-waste exposure in Ghana.

## **1.5 Research Questions**

- What is the prevalence of respiratory symptoms among e-waste workers and permanent residents at Agbogbloshie?
- Are permanent residents of Agbogbloshie at risk of developing cardio-respiratory health conditions?
- What is the cardiorespiratory health status of permanent residents compared to e-waste workers at Agbogbloshie?
- Are there any differences between the cardio-respiratory function indices of e-waste workers and permanent residents at Agbogbloshie?

## **1.6 Objectives**

### **1.6.1 General Objective**

- To assess the cardio-respiratory functions of e-waste workers and permanent residents at Agbogbloshie

### **1.6.2 Specific Objectives**

- To determine the prevalence of respiratory symptoms among e-waste workers and permanent residents at Agbogbloshie
- To measure oxygen saturation and blood pressure (BP) of e-waste workers and permanent residents using a pulse oximeter and a digital sphygmomanometer
- To measure Forced Expiratory Volumes (FEVs) and Forced Vital Capacities (FVCs) of e-waste workers and permanent residents using a spirometer

- To compare cardio-respiratory function indices among e-waste workers and permanent residents at Agbogbloshie

## CHAPTER TWO

### 2.0 LITERATURE REVIEW

#### 2.1 The burden of e-waste

All over the world, there is a steady surge in the production of electrical and electronic equipment (EEE) as information and communication technology assumed an important position in our lives. In the quest to keep up with technological advancement, faulty or outdated electrical and electronic gadgets are discarded for next generation ones. These gadgets, comprising of large quantities of refrigerators, computers, television sets, ovens, telephones and air conditioning units among others are usually exported to developing or underdeveloped economies, or end up at dump sites as electronic waste where they undergo processes for the extraction of valuable components embedded in them.

Each year, an estimated 50 million tonnes of e-waste is created worldwide with about 70-80% of them being exported to Africa and Asia (Baldé, Wang, Kuehr, & Huisman, 2015; A. Leung et al., 2006; Lundgren, 2012). E-waste is however, an emergent human and environmental health problem as researchers have linked exposures to adverse effects in the form of inflammatory responses and oxidative stress – determinants of cardiovascular and respiratory diseases, DNA damage and sometimes, cancer (Brook et al., 2010).

In the face of legislative challenges on the importation and recycling of e-waste in Ghana, the Agbogbloshie e-waste recycling site in Accra, serves as a typical example of places where large volumes of these condemned EEE are dumped continuously, with no regard for their potential to adversely impact the health of people living nearby and the

environment (Amoyaw-Osei et al., 2011). Adding to the problem are the processes involved in extracting valuable components such as open burning which releases toxic fumes into the surrounding atmosphere, affecting the health of the e-waste workers and vulnerable populations at large (Feldt et al., 2014).

## **2.2 E-waste recycling**

E-waste is known to contain a range of recyclable materials including copper, aluminum, iron and precious metals as well as plastics. These components, many of which are becoming scarce in nature are virtually integrated into each other and thus complicating the process of recycling compared to other products like paper or plastic. However, the depletion of raw material sources in the face of a growing demand for materials to manufacture new products, suggest the importance of collecting and recycling of obsolete products.

E-waste recycling can be carried out through both formal and informal ways. Formal e-waste recycling centres employs the use of equipment specially fabricated to carefully sort out recoverable materials from obsolete electronic devices and thus, protects workers from adverse health outcomes. These amenities however, are very expensive to construct and operate, and are less common in underdeveloped countries (Grant et al., 2013). Differences in existing national safety standards, can suggest that workers still risk low doses of exposure at these formal or semiformal recycling centres (Lundgren, 2012). Conversely, informal e-waste recycling employs such primitive methods as manual dismantling, open air burning of cables to retrieve copper, and then disposing of unsalvageable material in the sites. These methods lead to the release of heavy metals such as lead, mercury, cadmium

and nickel, and organic compounds such as flame retardants, and polychlorinated biphenyls into the environment and have the potential to cause harm to workers and communities (He et al., 2006; Labunska et al., 2008; Liu et al., 2009; Srigboh et al., 2016; Tsydenova & Bengtsson, 2011). Several studies have reported that metals and organic contaminants are linked with informal e-waste burning (Caravanos et al., 2011; Labunska et al., 2008).

Environmental pollution from e-waste recycling sites together with individual exposures of vulnerable workers constitute an incipient challenge in developing countries. The increasing doses of contaminants in food, water and the environment around e-waste sites, invariably put nearby residents at risk of being exposed, though at concentrations lesser than through occupational exposure (Lundgren, 2012). The informal recycling approach can lead to the discharge of highly toxic chemicals, which can have damaging health effects on the environment and humans, if not managed properly (M. Akormedi, Asampong, & Fobil, 2013).

### **2.2.1 Impact of e-waste on the environment**

Depending on the kind of operations of the e-waste workers involved, huge variations can exist in the levels of risk and hazards posed to the environment (Liu et al., 2009). Several studies from China provide evidence suggesting that the elementary recycling methods, together with the several tonnes of e-waste processed, have already ended in adverse impacts on the environment, including contaminated soil and surface water (Frazzoli, Orisakwe, Dragone, & Mantovani, 2010; Tsydenova & Bengtsson, 2011; Zhao et al., 2010). Halogenated persistent organic pollutants (POPs) such as PCBs used as dielectric or flame retardant plasticizers and brominated flame retardants (BFR) like polybrominated

diphenyl ethers (PBDE), polybrominated biphenyls (PBBs) were discovered in air, ash, dust, soil, water and sediment samples from e-waste recycling sites worldwide, in tremendously high concentrations. This is due to reckless burning and processing of the e-waste (Brigden, Labunska, Santillo, & Johnston, 2008; Jiang, Mei, & Feng, 2016; Liu et al., 2009; Wong, Duzgoren-Aydin, Aydin, & Wong, 2007).

At Agbogbloshie, the recycling of this e-waste is often carried out directly on a bare ground which releases toxic substances directly into the soil. The main fuel for fires at this site is a polyurethane-based insulating foam obtained from disassembled refrigerators and sometimes threadbare car tyres, both of which constitute acute chemical hazards and pollution of the burning sites in the long-term (Labunska et al., 2008). Soil and ash samples taken from the burning sites in Agbogbloshie showed extremely high concentrations of copper, lead, tin, antimony, cadmium and as compared to those typically seen in an uncontaminated soil (Labunska et al., 2008).

Other studies carried out at the recycling site also showed increased concentrations of lead, cadmium, and chromium in the soil. The concentrations of some of these metals found were over 50 times more than the maximum permissible exposure limits established by the World Health Organization (Velma, Vutukuru, & Tchounwou, 2009; Zayed & Terry, 2018).

Additionally, it has been observed that pollutants can traverse long distances and this can mean a risk of secondary exposure even in secluded zones. Air pollution stemming from burning and dismantling activities appears to be the major cause of occupational and

secondary exposure (Sepúlveda et al., 2010). Incomplete combustion of chlorinated organic materials, including PVC-coated wires, with the reaction being catalyzed by the presence of metals such as copper releases dioxins and furans (PCDD/F) in the form of fine ashes to places around the burning sites. This leads to air and surface soil pollution (Labunska et al., 2008). During the wet seasons, most parts of the recycling site become flooded with heavy rains which are likely to wash off surface dust, contaminated soil and leachate from the landfills into the nearby gutters, lagoons and the Odaw River which eventually runs off into the Atlantic Ocean. According to Labunska et al. (2008), high levels of chemical contamination were discovered in ash-contaminated soil samples from burning sites at Agbogbloshie as well as in sediments from a nearby shallow lagoon. They also reported comparatively low PCDD/F levels of 31pg/g Toxic Equivalent (TEQ) in ash contaminated soil at the Agbogbloshie market and much higher levels of about 1pg/g TEQ in sediments from the adjacent shallow lagoon.

Informal e-waste recycling activities also create the avenue for an environment-to food-chain contamination, as contaminants may be stored up in pastoral lands and ingested by grazing livestock. Most of these chemical contaminants of concern however have slow metabolic rates in animals, and hence, can bioaccumulate in tissues and be excreted via edible products such as eggs and milk. E-waste, therefore constitutes such a huge worldwide environmental and health emergency, with implications which transcend that of mere occupational exposure, involving vulnerable groups and future generations (Frazzoli et al., 2010).

### **2.2.2 Impact of e-waste recycling on human health**

The toxic effects associated with e-waste can be aggravated throughout an individual's lifetime and across generations. Health problems including diseases and conditions associated with the skin, stomach, respiratory tract and other organs have been reported in the last few years (Nordbrand, 2009). Workers are confronted with high incidences of birth defects, infant mortality, tuberculosis, blood diseases, anomalies in the immune system, malfunctioning of the kidneys and respiratory system, lung cancer, underdevelopment of the brain in children and damage to the nervous and blood systems (Prakash, Manhart, Amoyaw-Osei, & Agyekum, 2010). However, prospective cohort studies of e-waste workers are yet to be identified.

Studies reviewed by Song & Li (2014) showed that occupational exposure of e-waste workers and contamination of neighbouring communities were mainly the result of hazardous compounds released from informal e-waste recycling processes. The fine dust particles generated by the combustion is strongly associated in pulmonary and cardiovascular diseases, while the larger coarse dust particles which generally, cannot reach the human lungs, irritate the eyes, nose and throat. Again, e-waste workers may be exposed to PBDEs and dioxins as a result of atmospheric emissions.

Food items sold near the e-waste recycling site at Agbogbloshie can easily come into contact with the contaminated metallic dust containing PBDEs that is transported into areas outside the e-waste recycling site.

Furthermore, studies conducted among residents around the e-waste site showed high amounts of PCBs and brominated flame retardants (BFRs) in breast milk as well as heavy metals and OH-metabolites of aromatic hydrocarbons in urine (Asante et al., 2012; Feldt et al., 2014). Wittsiepe et al. (2015) found a clear impact of the e-waste exposure and exposure time on the internal PCDD/F i.e there was nearly a linear relationship between the time the e-waste workers had worked at the Agbogbloshie e-waste recycling site and their PCDD/F blood levels. There was also a negative effect of age on PCDD/F-levels from the study.

Most studies among e-waste workers have found direct influence of e-waste recycling site activities on internal PCB exposure using human milk samples using human blood samples (Bi et al., 2007; Wittsiepe et al., 2015; Xing et al., 2009). Again, at the Tianjin e-waste recycling site in Northern China, higher PCB serum levels were found among the dismantling e-waste workers (Yang et al., 2013).

### **2.3 Heavy metals exposure and cardio-respiratory health**

Heavy metals can be defined as those having relatively high densities or atomic weight, usually a specific density of more than 5 g/cm<sup>3</sup>. Heavy metals include lead, mercury, aluminum, arsenic, cadmium and nickel. Very low concentrations are found in the human body even though, in the earth's crust, they are widely distributed. Hence, exposure to even traces in the environment (atmosphere, soil, and water), can pose serious health threats to all organisms. Their main impact on human health is essentially through occupational exposure, contamination of the environment, and accumulation in food, mainly in vegetables cultivated on contaminated soil. Virtually all heavy metals are toxic in sufficient

quantities even though cadmium and arsenic, together with mercury and lead, have been recognized as the most probable causes of heavy metal-related disease observed in primary healthcare (Hu, 2000). Exposure to one contaminant of heavy metal is usually followed by exposure to others and hence, multiple interactions may occur in populations exposed to mixtures of metals.

Inhalation of fumes during burning operations is the most common source of acute exposure to these heavy metals leading to their absorption through the respiratory tract. Blood lead levels are an indication of a recent exposure (Lewis, 2007). Even though some organs seem particularly susceptible to specific heavy metals, the possible associations between arsenic, lead and mercury and cardiovascular diseases and related deaths have been recognized for many years (Navas-acien, Guallar, Silbergeld, & Rothenberg, 2007; Solenkova, Newman, Berger, & Thurston, 2014). In fact, several studies have indicated that a high prevalence of cardio-respiratory symptoms and diseases such as chronic cough, abnormal chest sound, shortness of breath, hypertension, carotid atherosclerosis and ischemic heart disease exist among subjects who are highly exposed to arsenic through drinking water (Abhyankar, Jones, Guallar, & Navas-Acien, 2012; Mazumder et al., 2000; Tseng et al., 2000). Lower forced expiratory volume in one second (FEV1) and altered forced vital capacity (FVC) were measured in these subjects (von Ehrenstein et al., 2005). Again, previous studies have shown that exposure to mercury compounds through the frequent and indiscriminate intake of fish by the population of the Amazon basin (Brazil), has a strong correlation with increased arterial blood pressure (BP) (Fillion et al., 2006; Houston, 2011).

The most robust studies determining an association between blood lead and cardiovascular outcomes have been conducted using data from the National Health and Nutrition Examination Surveys (NHANES). NHANES studies reported that even though there was a significant decrease in blood lead following the elimination of leaded gasoline, blood lead levels remained associated with cardiovascular outcomes of atherosclerotic origin, including coronary heart disease, hypertension, stroke, and peripheral arterial disease (Muntner, Menke, DeSalvo, Rabito, & Batuman, 2005; Navas-Acien, Selvin, & Sharrett, 2004).

#### **2.4 Particulate Matter Exposure and Cardio-respiratory Health**

Particulate matter (PM) refers to a complex amalgamation of all the dispersed and suspended solid and liquid particles in the air, many of which are potentially harmful. It comprises both organic and inorganic particles, including elemental carbon, carbon monoxide, sulfur and nitrogen oxides, mineral dust, pollen and liquid droplets. Particulate matter is linked with very serious air pollution-induced health effects and like other constituents of air, PM may have toxic constituents which can be conveyed into the airways.

The potential of PM to cause harm to exposed individuals is usually influenced by the PM size, which is also linked to its aerodynamic diameter (AD). Of high relevance to governments and health organizations globally, are the adverse health effects that arise due to exposure to particulate matter (PM), including particles with a median aerodynamic diameter less than 2.5  $\mu\text{m}$  (PM<sub>2.5</sub>) and less than 10  $\mu\text{m}$  (PM<sub>10</sub>) (Marks, 1994; WHO, 2006). Most PM<sub>10</sub> particles have an aerodynamic diameter ranging from 2.5  $\mu\text{m}$  to 10  $\mu\text{m}$

and can settle in the nasal sinuses and upper respiratory tract. PM<sub>2.5</sub> and PM<sub>0.1</sub> however, are particles with AD less than 2.5 µm and 0.1 µm respectively which may permeate the lung alveoli and enter into circulation, hence exerting their negative health effects (Brown, Zeman, & Bennett, 2002; Franck, Odeh, Wiedensohler, Wehner, & Herbarth, 2011a; Valavanidis & Fiotakis, 2008). In addition, studies on animal models have indicated that PM<sub>2.5</sub> can be engulfed by alveolar macrophages and endothelial cells, demonstrating a correlation between air pollution and direct adverse health effects (Brown et al., 2002; Franck et al., 2011b; Mills et al., 2006; Nemmar et al., 2001).

Generally, PM whose aerodynamic diameters are low, including fine and ultrafine (< 100 nm) PM, are linked with severe negative health effects after brief exposures to an elevated dose of pollutants or after long-term exposure (Franchini & Mannucci, 2007, 2009). Both acute and long-term exposures to PM and ambient air pollution (AAP) for that matter have been linked with diverse adverse cardio-respiratory events including hospital admissions with asthma, rhinorrhea, nasal obstruction, cough, dyspnea, and wheezing, angina, myocardial infarction, and heart failure and a lifetime risk of death from coronary heart disease (F. J. Kelly & Fussell, 2011; Mills et al., 2009). These adverse health effects can be aggravated among susceptible residents, especially those with pre-existing heart or lung diseases and the aged. Consequently, such inhabitants tend to have very complex health problems after exposure to air pollutants than healthy groups (Nawrot, Perez, Künzli, Munters, & Nemery, 2011).

Both clinical and epidemiological studies have consistently proven that air pollution is not only associated with morbidity and mortality resulting from airway and lung diseases, but

also cardiovascular diseases (Braga, Zanobetti, Schwartz, Luís, & Braga, 2001; R. D. Brook et al., 2015; WHO, 2005). The World Health Organization (WHO) in 2014 for instance, reported that in the year 2012, outdoor air pollution caused 3.7 million deaths worldwide, with 80% of these deaths attributable to cardiovascular diseases and 20%, respiratory diseases (WHO, 2014).

## **2.5 Particulate Matter Exposure and Cardio-respiratory Function**

Several studies evaluating the correlation between air pollution and cardiovascular disease have also examined possible alterations in blood pressure. Both air pollution and increased blood pressure are well-known to add on to an increased risk of cardiovascular disease. Again, a study by Zanobetti et al. (2004) revealed an association between particulate air pollution and a significant increase in blood pressure. According to their results, there was a 2.8 mmHg rise in patients' systolic blood pressure (SBP) when PM<sub>2.5</sub> goes up by 10.5 µg/m<sup>3</sup>. Diastolic blood pressure equally went up by 2.7mmHg in these patients in Boston. Analogous to this results, another study in Detroit estimated a 5.2mmHg increase in systolic BP with increased PM<sub>2.5</sub> levels (Brook, 2007). Also, in a study involving 23 normotensive individuals who were exposed to PM<sub>2.5</sub> and ozone (O<sub>3</sub>) for two hours, there were significant increases in diastolic BP (6 mmHg) (Urch et al., 2005). According to this research, there was a strong association between the carbon concentration in PM and the rise in blood pressure. Further, increases in SBP (2.6 mmHg) and DBP (2.4 mmHg) are significantly influenced by CO levels (De Paula Santos et al., 2005).

Studies conducted on the effect of PM on respiratory function also show that a rise in PM concentrations was strongly associated with decreases in pulmonary function for both acute

and chronic exposures (Downs et al., 2007; Gauderman et al., 2007; McCreanor et al., 2007; Chang et al., 2012).

## **CHAPTER THREE**

### **3.0 METHODS**

#### **3.1 Study Site**

This study was conducted at the Agbogbloshie e-waste recycling site in the Greater Accra Region of Ghana. The site is situated on the bank of the Odaw River and in the upper reaches of the Korle-Lagoon (Latitude 5.5508°/Longitude -.2134°). It is one of the largest e-waste dumps in sub-Saharan Africa, processing an estimated 129,000 tonnes of e-waste each year.

The Agbogbloshie site started as a food stuff market for onions and yam but has grown into a slum over the years with people dealing in all kinds of scrap. The slum describes a closely knitted settlement with a high proportion of the inhabitants living in wooden structures (shops/kiosks), some of which have no windows. Most damaged or waste electrical and electronic equipment from households and offices end up there every month as a final resting place. Recyclers then burn these waste materials in the open to recover valuable metals such as Copper for sale. The toxic smoke swirls around these workers and over Agbogbloshie, the roughly 20-acre scrap yard in the heart of Accra, Ghana, where these men live and work. Figure 3.1 below is a map showing Agbogbloshie.



*Figure 3.1: Map of Agbogbloshie, Accra – Ghana (Adapted from Amoyaw-Osei, 2011).*

### 3.2 Study Design

An analytical cross-sectional study was conducted to achieve the aim of the study. A structured questionnaire was administered to collect demographic data and also determine the prevalence of cardio-respiratory symptoms among both e-waste workers and permanent residents of Agbogbloshie. Cardio-respiratory function and respiratory symptoms were then compared among e-waste workers and permanent residents of Agbogbloshie.

### 3.3 Study variables

**Dependent variables:** Cardio-respiratory Function Indices and Symptoms

- Oxygen saturation (SpO<sub>2</sub>), blood pressure (BP), forced expiratory volume in one second (FEV1), the percentage of predicted FEV1 (FEV1%) forced expiratory capacity (FVC), the percentage of predicted FVC, FEV1/FVC ratio and FEV1/FVC ratio
- Respiratory symptoms: Cough, chest pains, sore throat, wheezing, shortness of breath, phlegm production

**Independent variables:**

- E-waste exposure

**Confounding variables:**

- Age, sex, occupation, cigarette smoking, exposure to environmental tobacco smoke, type of fuel used in cooking

### 3.4 Study Population

The source population comprised all e-waste workers and all persons who lived at Agbogbloshie at the time of the study. 100 participants, made up of 50 e-waste workers and 50 residents were selected from this population (see sections 3.5 and 3.6 for sample size calculation and sampling methods respectively). Inclusion criteria for the study were

- Participants had to be 18 years old and above and

- Occupation in e-waste recycling process not less than 6 months and residents who have lived at the dumpsite for at least 6 months at the time of the study.

Subjects were excluded if they;

- were not willing or able to understand or comply with study procedures.
- had a history of detached retina,
- had up to a 3-month history of stroke or heart attack and
- a history of coughing up blood in last month

### 3.5 Sample Size

It is currently not clear what the prevalence of cardio-respiratory disorders at Agbogbloshie is. However, Adams, Darko & Accorsi (2003) estimated an upper respiratory tract infection prevalence of 6.8% of the total outpatient visits in Ghana. It is also estimated that 4,500 to 6,500 individuals work at Agbogbloshie (Prakash et al., 2010). Thus, using the sample size calculation formula below:

$$n = Z^2pq/d^2,$$

where n = estimated sample size, Z = alpha value for the 95% confidence level - 1.96), p = the prevalence having upper respiratory tract infection symptoms, (Prevalence = 6.8) = 0.068, q = 1 - p = which is the probability of not having upper respiratory tract infection symptoms, in this case: 1 - p = 0.932, d = 0.05 as the acceptable margin of error,

$$n = \frac{(1.96)^2 (0.068) (0.932)}{(0.05)^2}$$
$$= 97$$

A non-response rate of 5% resulted in a sample size of 100. Thus, 50 e-waste workers and 50 permanent residents were selected to participate in the study. Previous studies among e-waste workers have used populations ranging from 39 to 75 (Asante et al., 2012; Feldt et al., 2014; Wittsiepe et al., 2015).

### **3.6 Recruitment/ Sampling Method**

The Principal Investigator together with the study team first approached the workers through a middleman (e-waste worker who is also resident at Agbogbloshie) and their informal association leaders prior to the data collection period where they introduced themselves and also informed the leaders of the purpose and procedure for the study. With the assistance of the local community guide, the team was taken round the recycling area and slum to familiarize ourselves with both the e-waste workers and the permanent residents. Both the e-waste workers and the permanent residents were also informed of the study purpose, procedure and timeline for the data collection.

Participants were sampled by convenience; based on their availability and who was willing to participate. Only e-waste workers and permanent residents who were available at the time of the data collection period and agreed to participate in the study and met the selection criteria were recruited. The middleman was depended upon to identify permanent residents and those who met the selection criteria and agreed to participate were included in the study.

All procedures and objectives for the study were explained to each participant in English and the local languages (via a hired translator) and informed consent was obtained prior to

participation. Participants were compensated for their involvement by way of free health advice and counselling and those with peculiar health problems were referred to nearby health facilities.

### **3.7 Data Collection Tools**

Data were sourced using a modified respiratory questionnaire, a spirometer for lung function measurement, a blood pressure monitor, pulse oximeter, a weighing scale and a stadiometer.

#### **3.7.1. Questionnaire**

The Interview questionnaire was in six parts. Part A captured general information including participants' assigned code, date and place of interview. The second part, B, determined information on demographic and personal data such as age, marital status (single, married, co-habiting), and highest level of formal education (No Formal Education, Primary, Junior High School, Senior High School). Part C asked information pertaining to living conditions and this included the type of accommodation, years of stay at Agbogbloshie, indoor cooking). Working conditions, common environmental exposures and cardio-respiratory symptoms (high blood pressure, cough, common cold and sneezing, wheezing, production of excessive phlegm) were also captured in Part D and E. The final part of the questionnaire, Part F ascertained lifestyle related issues such as cigarette smoking, exposure to environmental cigarette smoke, alcohol intake and use of recreational drugs.

A seventh part, Part G, was used to record participants' anthropometric and spirometric data.

### **3.7.2 Spirometry**

The highly portable EasyOne spirometer was used for the measurement of lung function (FVC, FEV1 and FEV1/FVC ratio). The Easy One spirometer is a portable, easy to read and use, battery-powered equipment with disposable mouthpieces. All data were automatically stored on this device and was later retrieved using a USB connection to a computer. The spirometer was used in conjunction with a stadiometer and a weighing scale for the measurement of height and weight required for performing accurate spirometry. The spirometer predicts lung volumes (expected lung volume for an individual) based on age, sex, height, weight, smoking habits, history of asthma and ethnicity (African, Asian, Caucasian).

### **3.8 Cardio-respiratory Function Testing**

A structured researcher administered questionnaire (Adopted from the ‘Recommended Respiratory Disease Questionnaires for Use with Adults and Children in Epidemiological Research, 1976’) was used to obtain participants’ demographic data (age, sex, educational level, type of recycling activity worker is engaged in, years of work and length of stay, use of personal protective equipment (PPE), smoking habits and current medications being taken, etc. The questionnaire was also used to ask about respiratory symptoms such as cough, common cold, wheezing, short breath and hospitalization secondary to acute respiratory infection and previously diagnosed hypertension. A written consent was sought from the participants before the questionnaire is administered. The questions were explained in the local language for those who do not speak English.

Then, anthropometric measurements to obtain height, weight, and body mass index (BMI) were taken. Study subjects were then placed in comfortable sitting positions to take blood pressure and heart rate recordings using a digital BP apparatus and pulse oximeter respectively. Subsequently, lung volumes were measured with a digital spirometer that meets widely accepted quality criteria. Participants were required to take in deep breaths and breathe out as fast as they can through the mouth piece (spirette) of a spirometer which recorded the following parameters: forced vital capacity (FVC), forced expiratory volume in the first second ( $FEV_1$ ),  $FEV_1/FVC$  ratio. As an infection control measure, each participant was given a new mouthpiece which was safely disposed of after use.

### **3.9 Training of research assistants**

Research assistants were trained prior to the start of the study. Training entailed an explanation of the questionnaire, ethics and seeking of informed consent from study participants. Questions in the questionnaire were explained to research assistants to prevent interviewer bias. They were trained to conform to the ethical guidelines of the study.

Again, the research assistants had a day – training programme on how to use the spirometer. This was facilitated by an occupational doctor from Germany who also doubled as a supervisor of this research work.

### **3.10 Data Processing and Analysis**

All the information on the questionnaire was entered into a computer database using the Stata/IC 15 software. The data were cross-checked to identify missing values and to address inconsistencies. Descriptive analyses were conducted on all variables assessed, including oxygen saturation and blood pressure (systolic and diastolic), forced expiratory volume in one second and forced vital capacity and demographic data of participants. Student's t-test and Pearson Chi square were used to compare means and proportions of cardio-respiratory function indices among e-waste workers and permanent residents and a 95% confidence interval ( $p < 0.05$ ) was used to test the significance level. Regression analysis was further conducted on all cardio-respiratory function parameters. Potential confounders such as age, passive smoking, smoking, recreational drugs use, indoor cooking and type of fuel use were added to the multiple linear regression model.

### **3.11 Spirometry Analysis – exclusion of participants**

The spirometry was dependent on the cooperation of the participants and therefore it was important to identify those participants with impaired spirometry results (FVC, FEV1) due to insufficient cooperation. It was therefore necessary to exclude those results since false impaired spirometry values will lead to a bias in the general analyses.

Spirometric data were excluded from the analyses, if  $FVC < 2.5$  l and  $FVC < 80\%$ , and  $SpO_2 \geq 98\%$ . Hence, spirometry was analyzed for 40 e-waste workers and 36 permanent residents.

### **3.13 Ethical consideration/issues**

Ethical clearance was sought from the Ghana Health Service Ethics Review Committee and approval was given for the implementation of the study protocol (GHS-ERC: 075/02/18). Permission was also sought from the informal group leaders at the recycling site.

The study objectives and procedures, as well as possible risks/ benefits associated with participating in the study, were carefully explained in English and the local language (Dagbani) to the e-waste workers before they were recruited. Persons who met the eligibility criteria for the study were recruited after they had given a written informed consent. Questionnaires were administered to those who agreed to participate and satisfied the inclusion criteria. Participants were informed about their right to stop at any point in the study. All responses obtained were kept confidential. Forms for each participant were kept under lock and key. The electronic data were locked with a password which is known to the principal investigator alone to prevent access to unauthorized people.

## CHAPTER FOUR

### 4.0 RESULTS

#### 4.1 Socio-Demographic characteristics of participants

A total of 50 e-waste workers and 50 permanent residents were recruited for the study, with mean ages  $25 \pm 7$  years and  $29 \pm 9$  years respectively. The mean age of both e-waste workers and permanent residents was  $27 \pm 8$  years. The ages of the e-waste workers ranged from 18 to 45 years while that of the permanent residents were from 18 to 55 years. The mean height and weight of e-waste workers and permanent residents were ( $169.9 \pm 6.8$  cm and  $166.0 \pm 8.3$  cm) and ( $66.7 \pm 8.1$  kg and  $67.8 \pm 10.2$  kg) respectively. The mean height and weight of all participants were  $167.9 \pm 7.8$  cm and  $67.2 \pm 9.2$  kg respectively. All the e-waste workers were males, and mostly single (72%). Majority, 23 (46%) dropped out of school at the Junior High School or Senior High School level. More than half (54%) of the participants were Moslems. Cigarette smoking was common among e-waste workers, 17 (34%) compared to the permanent residents, 5 (10%). Also, 32% of e-waste workers were into recreational drug use whereas 10% of the permanent residents used recreational drugs. In all, 45 participants comprising 18 (36%) e-waste workers and 27 (54%) permanent residents cooked in their places of residence. Less than a quarter, 18 (18%) of all participants (both e-waste workers and permanent residents) who lived at Agbogbloshie cooked indoors. The types of fuel used were Charcoal (82.2%), Wood/firewood (4.4%) and LPG/Gas (13.3%). Table 4.1 provides a summary of the demographic characteristics of the participants.

**Table 4.1: Socio-demographic Characteristics of E-waste Workers and Permanent Residents (n = 100)**

Characteristics of Study Participants	E-waste workers, n=50 N (%)	Permanent Residents, n=50 N (%)	Total, n=100 N (%)
<b>Age in years, (M ± SD)</b>	25 ± 7	29 ± 9	27 ± 8
<b>Height (m)</b>	169.9 ± 6.8	166.0 ± 8.3	167.9 ± 7.8
<b>Weight (kg)</b>	66.7(8.1)	67.8(10.2)	67.2 ± 9.2
<b>Sex</b>			
Male	50(100)	22(44)	77(77)
Female	0(0)	28(56)	28(28)
<b>Marital Status</b>			
Single	36(72)	31(62)	67(67)
Married	12(24)	16(32)	28(28)
Divorced	1(2)	2(4)	3(3)
Cohabiting	1(2)	1(2)	2(2)
<b>Religion</b>			
Christian	17(34)	27(54)	44(44)
Moslem	32(64)	22(44)	54(54)
Traditionalist	1(2)	1(2)	2(2)
<b>Educational level</b>			
No formal education	11(22)	12(24)	23(23)
Primary	15(30)	19(38)	34(34)
JHS	14(28)	13(26)	27(27)
SHS	9(18)	5(10)	14(14)
Others	1(2)	1(2)	2(2)
<b>Smoking Cigarette</b>			
Yes	17(34)	5(10)	22(22)
No	31(62)	45(90)	76(76)
In the past	2(4)	0(0)	2(2)
<b>Alcohol use</b>			
Yes	11(22)	13(26)	24(24)
No	39(78)	37(74)	76(76)
<b>Recreational drug use</b>			
Yes	16(32)	5(10)	21(21)
No	34(68)	45(90)	79(79)

**Table 4.1: Socio-demographic Characteristics of E-waste Workers and Permanent Residents, n = 100 (Continued)**

Characteristics of Study Participants	E-waste workers, n=50 N (%)	Permanent Residents, n=50 N (%)	Total, n=100 N (%)
<b>Cooking at home</b>			
Yes	18(36)	27(54)	45(45)
No	32(64)	23(46)	55(55)
<b>Indoor Cooking</b>			
Yes	6(12)	12(24)	18(18)
No	44(88)	38(76)	82(82)
<b>Fuel used by those who cook*</b>			
Charcoal	17(94.4)	20(74.1)	37(82.2)
Wood/firewood	0(0)	2(7.4)	2(4.4)
LPG/Gas	1(5.6)	5(18.5)	6(13.3)
<b>Years of work/ length of stay</b>			
6months – 1 year	14(28)	19(38)	33(33)
2 – 3 years	8(16)	12(24)	20(20)
4 – 5 years	5(10)	7(14)	12(12)
Over 5 years	23(46)	12(24)	35(35)
<b>Work days</b>			
4 days	2(4)		
5 days	2(4)	N/A	
6 – 7 days	46(92)		
<b>Working hours</b>			
4 – 5 hours	2(4)		
6 – 7 hours	2(4)	N/A	
8 hours	6(12)		
Over 8 hours	40(80)		

N/A – Not applicable

\* Percentages were computed using n = 45 (only those who cooked at home), n = 18 for e-waste workers and n = 27 for permanent residents.

#### 4.2 Prevalence of respiratory symptoms

Table 4.2 below shows the prevalence of self-reported respiratory symptoms among e-waste workers and permanent residents at Agbogbloshie. Excessive phlegm production was the most prevalent symptom among e-waste workers (84% vs. 62% in permanent residents) whereas permanent residents mostly reported sneezing (80% vs. 74% in e-waste workers) as their commonest respiratory symptom. Wheezing however, had the lowest prevalence among both e-waste workers, 12 (24%) and permanent residents, 4 (8%). Other respiratory symptoms as easy tiredness, chest pain, common cold, short breath and difficulty in breathing were all higher among e-waste workers than permanent residents.

**Table 4.2:** Prevalence of respiratory symptoms among e-waste workers and permanent residents

Symptom	Total, n=100 N (%)	E-waste workers, n=50 N (%)	Permanent residents, n=50 N (%)	Chi-square <i>p</i> -value
Cough	69(69)	33(66)	36(72)	0.517
Common Cold	75(75)	38(76)	37(74)	0.817
Sneezing	77(77)	37(74)	40(80)	0.476
Easy tiredness	77(77)	40(80)	37(74)	0.476
Chest pain	56(56)	30(60)	26(52)	0.420
Sore throat	44(44)	24(48)	20(40)	0.474
Excessive phlegm	73(73)	42(84)	31(62)	<b>0.013*</b>
Wheezing	16(16)	12(24)	4(8)	<b>0.029*</b>
Short breath	24(24)	14(28)	10(20)	0.349
Difficulty in breathing	25(25)	14(28)	11(22)	0.488

\**p* < 0.05 significance level (Pearson Chi-square)

### **4.3 Cardio-respiratory function of e-waste workers and permanent residents**

Cardio-respiratory function parameters were analyzed for both e-waste workers and permanent residents. However, as described under Section 3.11, spirometric data were excluded from the analyses, if  $FVC < 2.5$  l and  $FVC < 80\%$ , and  $SpO_2 \geq 98\%$ . Hence, spirometry was analyzed for 40 e-waste workers and 36 permanent residents. The mean systolic blood pressure for the e-waste workers was  $123.9 \pm 0.07$ mmHg and  $107.4 \pm 19.5$ mmHg for the permanent residents. Conversely, the mean diastolic blood pressure was higher for the permanent residents ( $83.3 \pm 14.9$ mmHg) as compared to the e-waste workers ( $76.5 \pm 10.1$ mmHg). Student t-test and Pearson Chi square were used to compare means and proportions respectively. There was significant difference in the diastolic BP of the two groups (p-value = 0.009). However, there were no significant differences between the means of the oxygen saturation ( $SpO_2$ ) and all lung function indices (FVC, FVC%, FEV1, FEV1%, FEV1/FVC, %FEV1/FVC). The results are as shown in Table 4.3.

**Table 4.3:** Cardio-respiratory function of E-waste Workers and Permanent Residents

	Total, n=100 N (%)	E-waste workers, n=50 N (%)	Permanent residents, n=50 N (%)	p-value
Systolic BP(mmHg), <b>Mean ±SD</b>	125.7 ± 17.2	123.9 ± 0.07	107.4 ± 19.5	0.31
Diastolic BP(mmHg)	79.9 ± 13.1	76.5 ± 10.1	83.3 ± 14.9	<b>0.009*</b>
<b>Hypertension</b>				
Normal	28(28)	14(28)	14(28)	
Pre-hypertension	19(19)	13(26)	6(12)	0.233
Hypertension	53(53)	23(46)	30(60)	
<b>Pulse (bpm)</b>	76.1 ± 12.7	73.3 ± 11.5	78.9 ± 13.2	<b>0.0271*</b>
Normal	86(86)	44(88)	42(84)	
Abnormal	14(14)	6(12)	8(16)	0.271
<b>SpO<sub>2</sub> **</b>	97.2 ± 1.9	97.1 ± 1.9	97.4 ± 1.9	0.5077
Normal	69(90.8)	36(90)	33(91.7)	
Abnormal	7(9.2)	4(10)	3(8.3)	0.548
<b>Lung function**</b>				
<b>FVC</b>	3.8 ± 1.7	4.08 ± 1.9	3.5 ± 1.3	0.1314
<b>FVC (% predicted)</b>	95.4 ± 39.9	97.4 ± 41.5	93.2 ± 38.5	0.651
<b>FEV1</b>	2.9 ± 2.5	3.14 ± 3.1	0.60 ± 1.0	0.373
<b>FEV1 (% predicted)</b>	78 ± 27.5	75.4 ± 20.8	80.9 ± 33.5	0.3797
<b>FEV1/FVC</b>	72.5 ± 17.0	69.5 ± 18.8)	75.8 ± 14.4	0.1086
Normal	54(71.1)	26(65)	28(77.8)	
Abnormal	22(28.9)	14(35)	8(22.2)	0.289
<b>FEV1/FVC (% predicted)</b>	84.9 ± 19.9	80.6 ± 22.1	84.9 ± 19.9	0.1252
Normal	52(68.4)	25(62.5)	27(75)	
Abnormal	24(31.6)	15(37.5)	9(25)	0.626

\***p < 0.05** significance level (**p – values** are from a Student t-test and Pearson Chi square comparing means and proportions respectively between e-waste workers and permanent residents.

\*\*Data analyzed for 40 e-waste workers and 36 permanent residents.

#### **4.4a Predictors of cardio-respiratory function of e-waste workers and permanent residents**

Further multiple linear regression analyses were conducted on the cardio-respiratory function indices among e-waste workers and permanent residents and the results detailed in Table 4.4a and Table 4.4b below.

The results (Table 4.4a) indicate that recycling activity and number of work days had significant influence on diastolic blood pressure.

Age, passive smoking, smoking, recreational drugs use, indoor cooking and type of fuel use have been reported in literature as confounders and hence, added to the multiple linear regression model (as shown in Table 4.4b).

**Table 4.4a:** *Predictors of Cardiorespiratory function for E-waste workers*

Parameters		Recycling Activity	Years of work	Working hours	Work days	PPE use
SpO <sub>2</sub>	Coefficient	0.311877	0.132961	-0.381	0.5797533	0.712063
	P value	0.441	0.635	0.551	0.572	0.363
SYSTOLIC	Coefficient	2.008136	-2.14265	-2.49721	3.268391	2.703273
	P value	0.484	0.241	0.488	0.607	0.601
DIASTOLIC	Coefficient	4.845554	0.574869	-3.28288	9.211116	-3.26048
	P value	0.008	0.606	0.142	0.022	0.307
FVC	Coefficient	-0.51492	0.151698	0.464944	0.7246385	-0.09181
	P value	0.214	0.594	0.474	0.487	0.907
FVC%	Coefficient	-2.013685	-3.977878	13.21836	17.28282	2.89455
	P value	0.824	0.950	0.358	0.454	0.868
FEV1	Coefficient	-0.57721	0.152115	0.808409	0.1687097	0.826657
	P value	0.423	0.76	0.477	0.926	0.551
FEV1%	Coefficient	.3933123	1.115727	6.21291	8.104971	-1.546422
	P value	0.930	0.722	0.386	0.481	0.859
FEV1/FVC	Coefficient	1.771176	-1.33937	2.30349	-3.779596	0.787359
	P value	0.671	0.644	0.726	0.721	0.922
FEV1/FVC (%)	Coefficient	2.479029	-1.407527	2.409493	-4.029567	-0.0332564
	P value	0.631	0.679	0.755	0.746	0.997

Multiple linear regression analysis of cardio-respiratory function indices, controlling for recycling activity, years of work, working hours, work days and use of PPE (personal protective equipment)

#### **4.4b Predictors of cardio-respiratory function of e-waste workers and permanent residents**

The multiple linear regression analyses (Table 4.4b), adjacent show that potential confounders such as age, passive smoking, indoor cooking and type of fuel used had significant influence on the respiratory function parameter (FVC%).

Again, age and smoking had significant influence on the diastolic blood pressure.

Furthermore, the results indicate the recreational drug use has significant influence (p-value = 0.028) on FEV<sub>1</sub>.

**Table 4.4b:** Predictors of Cardiorespiratory function for E-waste workers and permanent residents at Agbogbloshie

Parameters		Age	Passive smoking	Smoking	Recreational drugs	Indoor cooking	Type of fuel
SpO <sub>2</sub>	Coefficient	-0.02761	-1.0864	0.101315	-1.03054	-1.19998	-0.48484
	P value	0.519	0.204	0.9	0.232	0.121	0.414
SYSTOLIC	Coefficient	1.205974	9.319604	11.57273	-10.0404	12.16411	3.576529
	P value	<b>0.009</b>	0.261	0.128	0.48	0.193	0.56
DIASTOLIC	Coefficient	0.51428	2.80946	11.97609	-14.7237	5.719699	3.13309
	P value	<b>0.05</b>	0.559	<b>0.01</b>	0.085	0.293	0.385
FVC	Coefficient	0.027244	0.658419	0.768803	0.106599	-0.59515	0.387451
	P value	0.331	0.231	0.162	0.842	0.222	0.316
FVC%	Coefficient	1.310334	22.65898	13.81982	-2.7879	-24.3	16.39411
	P value	<b>0.025</b>	<b>0.04</b>	0.175	0.78	<b>0.017</b>	<b>0.037</b>
FEV1	Coefficient	-0.20358	-3.02118	-3.64501	8.364885	1.5464	-3.27444
	P value	0.248	0.369	0.276	<b>0.028</b>	0.599	0.182
FEV1%	Coefficient	1.147071	16.64735	9.395931	-2.05952	-19.1861	19.4601
	P value	0.12	0.231	0.482	0.879	0.128	0.063
FEV1/FVC	Coefficient	-0.17359	-2.09716	-4.1613	-0.21352	1.791302	4.900253
	P value	0.747	0.84	0.685	0.984	0.846	0.512
%FEV1/FVC	Coefficient	-0.06608	-2.9173	-3.22628	0.055425	1.60636	5.440489
	P value	0.918	0.814	0.792	0.996	0.884	0.542

Multiple linear regression analysis of cardio-respiratory function indices, controlling for age, passive smoking, smoking, recreational drugs use, indoor cooking and type of fuel used in cooking

## **CHAPTER FIVE**

### **5.0 DISCUSSION**

#### **5.1 Introduction**

‘Cardiorespiratory function’ simply describes the efficiency of the heart in relation to the body's entire breathing mechanism. It is a well-known fact that informal e-waste recyclers are exposed to environmental pollutants which have potential negative impacts on their health (Akormedi, Asampong, & Fobil, 2017). Studies however, on nearby populations around these sites are rare and one on cardiorespiratory function has not been identified yet. The present study aimed to assess the cardio-respiratory functions of e-waste workers and permanent residents at Agbogbloshie but no significant differences in the parameters were recorded except for diastolic blood pressure.

#### **5.2 Methodological validity**

This was the first study to have compared the cardio-respiratory functions of e-waste workers and permanent residents. A structured questionnaire was used to collect data on demographics and environmental exposures and objective measures of cardio-respiratory function were recorded thus, minimizing the influence of information bias. The study also controlled for important confounders such as age, cigarette smoking, environmental tobacco smoking, indoor cooking and type of fuel used in cooking. This was achieved by adding the confounders to the multiple linear regression model. The main challenges were the unavailability of the e-waste workers and language barrier. To overcome this hurdle, a native Dagomba was employed to assist with interpretation of questionnaire and general

communication. The major limitation of the study however, was the fact that it was a cross-sectional design thus, precluding any causal association.

### **5.3 Comparing study results with previous findings**

E-waste workers were mainly young Ghanaian men, single and had little or no formal education. Previous studies also reported that electronic waste recycling work in Ghana was a male dominant activity due to the physical strength required and that most of the e-waste workers who burned materials were young men in their late teens and early twenties, quite youthful with no or low formal education and thus have reduced employability (M. Akormedi et al., 2013; Oteng-Ababio, 2012). According to previous studies, majority of e-waste workers did not use respiratory protective equipment and had poor knowledge of respiratory hazards associated with their work (Akormedi, Asampong, & Fobil, 2017; Akormedi, 2012). Again, by merely observing, one could easily tell that these workers idea of what a standard PPE is, is far from what they were using. For instance, some workers who said they used safety boots were wearing ordinary canvas or sneakers to work. This observation brings to bare the need for educating especially e-waste workers on the health-related hazards and risk associated with their work as well as how to prevent them. Both e-waste workers and permanent residents reported cough (66% vs. 72%), cold (76% vs. 74%), excessive phlegm production (84% vs. 62%), sneezing (74% vs. 80%), easy tiredness (80% vs. 74%) and chest pain (60% vs. 52%) as common respiratory symptoms. Comparing these results to those of a previous study by Amoabeng-Nti (2015), self-reported respiratory symptoms, though common among e-waste workers at Agbogbloshie had relatively lower prevalence rates; cough (37%), cold (36.4%), excessive phlegm (45.5%) and easy tiredness (63.6%). Another study by Mohan et al. (2000) reported that

23% of community residents living near waste disposal incinerators reported morning cough and phlegm production as a self-reported respiratory symptom. As suggested by previous studies, this increase in prevalence rates of respiratory symptoms at Agbogbloshie could be attributed to the persistence of air pollutants especially dust and smoke within the community over the period (Politis, Pilinis, & Lekkas, 2008; R uckerl, Schneider, Breitner, Cyrus, & Peters, 2011; Wichmann et al., 2006). The landscape at Agbogbloshie, is such that depending on the wind direction, one can almost always experience dust particles adhering to the body and hence, a high chance of inhaling these particulates.

According to the American Heart Association, normal blood pressure is below 120/80 mm Hg (systolic/diastolic). Therefore the mean blood pressures for e-waste workers (104/77mm Hg) and permanent residents (107/83mm Hg) were normal (approximating the diastolic BP to the nearest ten). However, 23(46.9%) of the 50 e-waste workers had high blood pressure compared to a relatively higher proportion of the permanent residents, 30(60%). This increase in prevalence of high blood pressure among these participants could be associated with polluted air (particulate matter) exposure, as explained by several studies (Hicken et al., 2014; Sughis, Nawrot, Ihsan-ul-Haque, Amjad, & Nemery, 2012). However, this observation is more likely to have been influenced by the increase in the mean age of permanent residents ( $29 \pm 9$  years) compared to the e-waste workers ( $25 \pm 7$  years). Further multiple linear regressions models were used to examine the health effects. The results showed that both systolic and diastolic BP increased with increase in age, environmental tobacco smoking, cooking indoors and type of fuel used. In finding an association between long-term air pollution and increased blood pressure and hypertension in China, Dong et al., (2013) reported the odds ratio for hypertension increased by 1.12

(95% confidence interval [CI], 1.08–1.16) per 19  $\mu\text{g}/\text{m}^3$  increase in PM<sub>10</sub>, even though the associations were only statistically significant in men. On the contrary, the model showed that blood pressure decreased with recreational drug use, which among the study participants was mostly “wee” (cannabis), used by 32%. A study by Alshaarawy & Elbaz (2017) however showed that there was no association between cannabis use and blood pressure.

According to the British Thoracic Society, spirometry indicates the presence of an abnormality if any of the following are recorded: FEV<sub>1</sub> < 80% predicted normal, FVC < 80% predicted normal and FEV<sub>1</sub>/FVC ratio < 0.7. The means of FVC, FVC% and FEV<sub>1</sub> were lower for the permanent residents compared to the e-waste workers, even though no significant differences were found. This result can be explained by the fact that respiratory symptoms were highly prevalent in both e-waste workers and permanent residents which could also mean that both e-waste workers and permanent residents had common exposures such as dust, smoke and other air pollutants. Any difference in exposure may be accounted for by changes in wind direction, frequency of exposure and the proximity to the pollutants. Most of the permanent residents at Agbogbloshie live in rented kiosks, some with no windows. This creates the potential for polluted air to be trapped indoors and hence affecting indoor air quality which could result in respiratory tract infections and for that matter, respiratory symptoms. Again, the mean of the predicted FEV<sub>1</sub>, FEV<sub>1</sub>% ( $75.4 \pm 20.8\%$  vs.  $80.9 \pm 33.5$ ) and FEV<sub>1</sub>/FVC ( $69.5 \pm 18.8\%$  vs.  $75.8 \pm 14.4\%$ ) were lower among e-waste workers. Comparing this result with that of Amoabeng Nti (2015), the mean FEV<sub>1</sub>/FVC for e-waste workers at Agbogbloshie was  $83.55 \pm 15.02\%$  which suggests a decreasing trend in the respiratory function of e-waste workers. This could be explained by

the multivariate regression model in Table 4.4a which suggests that FEV1/FVC decreases with increasing number of years as an e-waste worker even though the relationship was however not statistically significant.

## CHAPTER SIX

### 6.0 CONCLUSIONS AND RECOMMENDATIONS

#### 6.1 Introductory Statement

Informal e-waste recycling processes are associated with the release of pollutants that can be detrimental to human health. These health effects may not only be limited to the individuals directly involved in these e-waste activities but also, vulnerable human populations nearby. A clear understanding of the health effects of these crude practices, could infer the appropriate actions by policy makers and law enforcers to ensure sanity in our communities.

A cross-sectional analytical study was conducted with the aim of assessing the cardio-respiratory functions of e-waste workers and permanent residents at Agbogbloshie. This study involved 100 participants (50 e-waste workers and 50 permanent residents) from the Agbogbloshie community in Accra, Ghana. A well-structured respiratory questionnaire, a spirometer for lung function measurement, a blood pressure monitor, pulse oximeter, a weighing scale and a height meter were used as guide to interview and assess cardio-respiratory function.

The results showed that e-waste workers and permanent residents had common environmental exposures and hence, shared respiratory symptoms. Though a slight increase and significant difference in diastolic BP was recorded for permanent residents the means of blood pressure and oxygen saturation were both normal for e-waste workers and permanent residents. There was no significant difference in cardio-respiratory function among e-waste workers and permanent residents.

## 6.2 Conclusion

From this study, it can be concluded that:

- Higher prevalence rates of respiratory symptoms exist among e-waste workers compared to the permanent residents
- The mean diastolic BP of permanent residents was relatively high compared to the e-waste workers and there was a significant difference in means. Hence, permanent residents may have an increased risk for isolated diastolic high blood pressure.
- Both e-waste workers and permanent residents have no significant difference in their cardiorespiratory function implying that cardio-respiratory function is the same

## 6.3 Recommendations

Based on the study results it is recommended that:

- There should be an immediate policy development and law enforcement on a ban of crude e-waste recycling practices such as open air burning which pose as environmental and human health hazards
- There is the need to adopt modernized and less hazardous e-waste recycling practices to help minimized exposure levels and hence protect both workers and vulnerable populations nearby.

- Again, both e-waste workers and permanent residents should be educated on the hazards and risk associated with their work or otherwise, stay in the Agbogbloshie community and how they can minimize exposures (for example, use of personal protective equipment)
- There must be an increased surveillance within Agbogbloshie and its surrounding communities for a timely identification and investigation of possible health threats

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## APPENDICES

### 7.1 Informed Consent Form

**Title of study:** Comparative analysis of cardiorespiratory function among e-waste workers and permanent residents at Agbogbloshie, Accra

#### **Introduction**

I am a master's student of the School of Public Health, University of Ghana, Legon. As part of the programme, we carry out research work. My work is on the health effects of coming into contact with electronic waste (e-waste). E-waste recyclers in Agbogbloshie use the manual dismantling and open-air burning to retrieve some valuable metals which render them and the surrounding community to mixtures of poisonous substances such as fumes of lead, mercury and arsenic through breathing, by mouth and through the skin. These chemicals are known to have severe negative health effects on humans.

It is hoped that the findings of this study will help identify whether living at Agbogbloshie exerts the same levels of exposure to e-waste and hence, same health consequences as among e-waste workers.

#### **Purpose of the study**

The study aims at comparing the efficiency of the heart and lungs of permanent residents to e-waste workers at the Agbogbloshie dumping/recycling site.

#### **Eligibility criteria**

Anyone who is 18 years or older and has been involved in the e-waste recycling process or lived at Agbogbloshie for not less than 6 months can take part in the study.

Persons who are not willing or able to understand or comply with study procedures will be excluded as well as those with a history of detached retina, those with up to a 3-month history of stroke or heart attack and a history of coughing up blood in last month.

### **Study Procedure**

A short interview will be conducted to obtain the contact information, age, sex, highest educational level, ethnicity, type of recycling activity one is engaged in, hours of work per week, years of work in e-waste recycling, use of protective clothing, location and distance of your work area from burning site, smoking habits, alcohol use and current medications that you are taking.

Blood oxygen saturation, blood pressure and heart rate will be recorded using a pulse oximeter and digital BP apparatus fixed to the arm of participants by the principal investigator. The volume of air participants can forcefully breathe out will then be measured by means of the mouthpiece of the digital spirometer. Maximum of three (3) recordings will be taken for each measurement.

### **Risks and Benefits**

This research will increase our understanding regarding the possibility of harm to the heart and lungs when you come into contact with e-waste and also find whether living at the e-waste site induces the responses in the function of the heart and lung when exposed to ambient air pollution. A better understanding of these relationships may provide information to put in place measures to protect the workers and residents alike, at e-waste sites. Furthermore, this research may provide evidence to support the need for infrastructure in Ghana for the safe disposal of e-waste and also provide critical

environmental and occupational health research practical for the principal investigator, Francis Agyen Frimpong at the School of Public Health, University of Ghana. The laboratory tests will be done for free.

Spirometry as well as BP monitoring are very low-risk tests. However, blowing out hard can increase the pressure in your chest, tummy (abdomen) and eyes and can be discomforting. Possible risk of cross infection or contamination of spirometer mouthpiece will be avoided ensuring strict hygienic handling practices and using a sterile mouthpiece for each participant.

### **Freedom to participate/ Voluntary withdrawal**

Participant opinions and experiences are important to us, so we want you to be honest and truthful in answering our questions. Your participation is completely voluntary and you may refuse to participate at any time. You may ask me to stop the interview or cardiorespiratory function tests at any point or you may also decline to answer any question if it makes you uncomfortable.

### **Privacy and Confidentiality**

To ensure confidentiality and privacy we will not mark any data collected with study participant's names: rather we will code numbers to the individual data and keep an encrypted file that coordinates numbers to names on a secure laptop.

### **Protection of subjects' privacy**

Participants do not have to answer any questions that they feel are an invasion of their privacy. Also, subjects do not have to participate in any particular aspects of the study that they find invasive. Results from their cardiorespiratory function test will be communicated

directly to them through the contact details they will provide. Additionally, client with abnormal test results will be assisted with a referral letter to the appropriate facility.

**Provision to prematurely end a particular subject's participation in the study**

Participants can opt to be interviewed in a location of their choice to increase privacy. In the case of an adverse event or situation of distress, a subject's participation in the study will be concluded.

**Data storage and protection**

All research records and data will be protected against inappropriate use or disclosure, or malicious or accidental loss or destruction. Data will be locked with restricted access on a secure laptop. There will be safe disposition/destruction of data or devices, as appropriate (e.g., shredding paper documents, secure erasure of electronic media) at the conclusion of the study.

**Declaration of conflict of interest**

I, Francis Agyen Frimpong (Principal Investigator), declare that, to the best of my knowledge, there is no actual, perceived or potential conflict of interest that will or may arise as a result of my involvement with this study.

**Who to contact**

In cases of any questions regarding the research, you can contact:

- GHS/ Ethical Review Committee administrator, Hannah Frimpong (Mobile: 0507041223),
- School of Public health, University of Ghana, Legon.

or

- Francis Agyen Frimpong  
Mobile number: 0242289059/ 0206479195  
Email: fafrimps@gmail.com

**Before taking Consent**

Do you have any questions you wish to ask about the study? Yes  No

(If yes, please, indicate the questions

below).....

.....

.....

**Statement of consent**

I ....., declare that the purpose, procedures to be followed, risks and benefits of the study have been read/ had been explained and every

question(s) have been answered to my satisfaction. I hereby give consent to participate in this study.

Signature/Thumbprint \_\_\_\_\_ of \_\_\_\_\_ participant.....

Date...../...../.....

**Statement by the Researcher**

I, undersigned, have explained this consent form to the subject in the language that he/she understands on information regarding this study. I agree to answer any future questions concerning the study and also adhere to the approved protocol.

Signature .....

Date...../...../.....