AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND ENTREPRENEURIAL DEVELOPMENT

OCCUPATIONAL HEALTH AND SAFETY PRACTICES AMONG ARTISANS INVOLVED IN LEAD-ACID BATTERY RECYCLING AT SUAME MAGAZINE IN THE KUMASI METROPOLIS

CHARLES LEO OBENG

MARCH, 2024

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BY

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MARCH, 2024

DECLARATION

Candidate's Declaration

I hereby declare that this thesis is the result of my original work and that no part of it has been presented for another degree in this university or elsewhere.

Charles Leo Obeng

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

Supervisors' Declaration

We hereby declare that the preparation and presentation of this thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development.

Professor Emmanuel Dartey (Principal Supervisor)

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

Professor Bismark Dwumfour-Asare (Co-Supervisor)

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

ABSTRACT

Lead acid battery recycling plays a pivotal role in the global effort towards sustainable waste management and resource recovery. However, artisans engaged in this process face various occupational health and safety challenges due to the inherent hazards associated with lead exposure and other toxic substances present in the batteries and this is coupled with many artisans not being fully informed about the potential health risks associated with lead exposure or the correct usage of personal protective equipment. The present research investigated the safety and health at work procedures of artisans engaged in lead-acid battery recycling and evaluated the levels of lead in the soil and air. The study was carried out at Lead Acid Battery workshops located in Suame Magazine, and data was collected through the use of questionnaires used to assess artisans' knowledge and practices related to health and safety. Twenty-one workshops were selected using the snowball sampling technique and air and soil samples were taken from where artisans worked on battery recycling and from their resting places. The age ranges of 31-40 and 41-50 were most common among artisans. Most contact with lead lasted for 30 minutes. Waste was primarily disposed of by selling it as scrap. Nose mask usage was only 23.8% of workshops for protection against gas emissions. Lead concentrations ranged from 0.37 to 4.18mg/kg in air particulates, 33.40 to 92.51mg/kg in soil outside the workshops, and 7.25 to 84.50mg/kg in soil inside the workshops. Hazard quotient values for inhalation did not exceed a maximum level of 1. Differences in measured lead levels among workshops were not significant and this occurred at a p-value of 0.52. The study concluded that workers in lead acid battery recycling lacked proper PPE (14.3% use of gloves and other Personal Protective Equipments) and awareness of lead's dangers, leading to no protection against exposure. While current levels of lead exposure may not pose immediate risks, long-term exposure could lead to health complications. Detectable levels of lead (Pb) were found in air and soil samples from LAB recycling workshops, with varying distribution ranges. The study recommended educating artisans on health hazards, enforcing regulations on PPE use, and implementing proper ventilation systems to minimize lead exposure.

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DEDICATION

I dedicate this piece to my parents Mr. Charles K. Obeng and Mrs. Grace Obeng, siblings and my lovely wife Mrs. Nyarkoa Osae Obeng and Anthony Leo-Obeng, Jessica Leo-Obeng, Ivan Leo-Obeng and Gracelyn Leo-Obeng.

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ADD	Average Daily Dose
ADDderm	Average Daily Dose Dermal
ADDinh	Average Daily Dose Inhalation
ASA	Soil sample inside the workshop
ASB	Soil sample outside the workshop
Crderm	Carcinogenic Risk Dermal
Crinh	Carcinogenic Risk Inhalation
FAO	Food and Agriculture Organization
HQ	Hazard Quotient
LAB	Lead-Acid Battery
OHS	Occupational Health Safety
WHO	World Health Organization
UPS	Uninterrupted Power Supply

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The use of lead acid batteries (LAB) dates back the very beginning of the use of power storage systems. In fact LAB have been acclaimed as the oldest yet still very popular battery technology for storing power (EHS, 2014; Enos, 2014). They have been utilized in various power systems, spanning from small-scale business energy storage systems like uninterrupted power supply (UPS) to huge grid-scale power systems (Spataru & Bouffaron, 2022). There is expected increase in production and sales of automobiles, solar power systems and electronic appliances, and the LAB recycling industry keeps expanding throughout the world. This expansion comes with the concomitant hazards associated with lead use, especially those associated with widespread artisanal LAB recycling (Cossa et al., 2021).

Artisanal and non-regulated recycling of LAB are predominantly practiced in several parts of the world, resulting in lead exposure and poisoning to young children in particular who are known to be at greatest risk (Daniell et al., 2015). The risk of lead exposure and poisoning in the general population is exacerbated by the practice of unregulated recycling of LAB in densely populated urban centers (Wekoye, 2019). The consequence of this is that these recycling activities have the capacity to impact a significant number of individuals due to the shortage of environmental controls, if any (Chowdhury et al., 2021). Generally, artisanal lead-acid battery recycling in countries without lead-refinery have been sufficiently explained in the literature (Lee Crawfurd et al., 2023) According to Varshney et al. (2020), four main stages of the recycling process have been identified to include; waste battery collection, acid drainage, battery breaking and lead scrap extraction and smelting of raw lead ingots.

Safety management, as defined by Kukoyi & Adebowale (2021), encompasses a series of actions or protocols concerning health and care within a work environment. The method comprises three primary duties: hazard detection, precautionary planning, and monitoring. Kreshpaj et al. (2022) found evidence indicating that certain workplaces experience a high frequency of injuries, whereas others with comparable tasks have either no injuries or fewer. Differences have been noted in the implementation of occupational health and safety initiatives in various companies. Workplace safety and health management is a crucial component of management in Ghana, as stated by Boadu (2022). Success requires management's dedication to health and safety, professional autonomy, privacy, and collaboration between management and employees. Occupational Health Safety management, as described by Siabi et al. (2022), involves overseeing the mental, social, and physical well-being of workers, including the entirety of the individual.

A labor force's working capacity supports the material and economic foundation of a society. Workers' occupational health and safety are essential requirements for productivity and play a crucial role in socio-economic and sustainable development (Adu-Gyamfi, 2019). At least seven percent of Ghana's GDP is spent on addressing issues related to the inadequate management of health and safety (Nyarko, 2021). According to (Yin et al., 2023) over the past few decades, maintaining the protection of staff from job-related accidents and diseases has become a major concern for workers, employees, governments, and the general population in Ghana. In Ghana, legislation concerning the management of employees' Occupational Health and Safety (OHS) at the workplace are disjointed. Implementing these legislation faces several obstacles due to loopholes in the current laws governing OHS management (Adei et al., 2021). Lambert (2005) suggests that efficient management of work environment safety can lead to increased productivity beyond the initial level reported (Jahandoost et al., 2021). Policy-level initiatives in the management of safety and health and the promotion of employee well-being are crucial, especially when they involve increased stakeholder involvement through mechanisms such as collective agreements and enterprise responsibility (Schulte et al., 2022). This will ensure compliance with safety rules. Kim & Park, (2020) found that enterprises tend to adhere to health and safety rules after experiencing occupational injuries in previous years. Institutions like the Trades Union Congress in Ghana aim to implement health and safety measures and create employee unions in enterprises to enhance the working conditions for employees (Adu-Gyamfi, 2019). These entities typically safeguard workers who decline to undertake risky duties and provide assistance and advocacy for workers involved in accident compensation cases (Schulte et al., 2022).

1.2 Problem Statement

Lead acid battery recycling plays a pivotal role in the global effort towards sustainable waste management and resource recovery (Yanamandra et al., 2022). However, artisans engaged in this process face various occupational health and safety challenges due to the inherent hazards associated with lead exposure and other toxic substances present in the batteries (Afolabi et al., 2021a). Occupational Safety and Health Administration (OSHA) emphasizes the adverse effects of lead exposure on the nervous, hematopoietic, renal, and reproductive systems (OSHA, 2022).

Many artisans may not be fully informed about the potential health risks associated with lead exposure or the correct usage of personal protective equipment (PPE) (Ishak & Obeng-Ofori, 2022). Inadequate provision and usage of personal protective equipment (PPE) among artisans engaged in lead acid battery recycling have been reported (Kitui, 2022). Absence or improper use of PPEs, such as respirators, gloves, and protective clothing, significantly increases the risk of lead absorption through inhalation, ingestion, and dermal contact (Garrigou et al., 2020). This points to a critical gap in occupational safety practices that requires urgent attention.

Moreover, reports suggest that some recycling facilities lack adequate ventilation measures and comprehensive training and awareness programs which contribute to the elevated levels of lead in the air (NIOSH, 2018) exacerbates the risk of lead exposure for artisans and calls for improvements in facility infrastructure. Addressing these issues is critical for safeguarding the well-being of artisans and promoting sustainable practices in lead-acid battery recycling.

Therefore, strengthening regulatory frameworks, ensuring regular inspections, and imposing penalties for non-compliance are essential steps to promote a culture of safety in the industry (WHO, 2020).

Due to the limited study in this area, this research seeks to investigate the artisans' adherence to workplace safety and health practices involved in lead-acid battery recycling as well as to assess the level of lead in the soil and air borne particulate matter.

1.3 Objectives of the Study

The main objective of this study is to assess the occupational health and safety practices among artisans involved in lead-acid battery recycling at Suame magazine in the Kumasi metropolis.

The specific objectives of this study are:

1. To assess artisanal LAB recycling workers' awareness of required OHS measures.
2. To assess key workplace occupational health and safety practices among LAB recycling workers.
3. To assess the level of lead levels in air borne particulate matter and soil in and around LAB recycling workshops.
4. To determine the human health risks (carcinogenic) associated with lead exposure among LAB recycling workers.

1.4 Research Questions

The specific questions which drive the research are:

1. What is the artisanal LAB recycling workers' awareness of required OHS measures?
2. What are the workplace OHS practices of LAB recycling workers (the accessibility and utilization of Personal Protective Equipment, PPE)?
3. What is the level of lead exposure in air borne particulate matter and soil in and around LAB recycling workshops?
4. What is the human health risk associated with lead exposure in LAB recycling workshops?

1.5 Justification for the Study

Suame Magazine is a renowned industrial hub in the Kumasi Metropolis of Ghana. It hosts a significant number of artisans engaged in diverse activities, including lead-acid battery recycling. Studying OHS practices in this specific location will contribute to a comprehensive understanding of the occupational health and safety situation in the informal sector, not only in Suame Magazine but also in similar industrial clusters globally. Artisans involved in lead-acid battery recycling are exposed to various occupational hazards, such as lead poisoning, acid burns, and respiratory issues. Therefore, studying the OHS practices in this specific context is essential to identify potential risks and develop strategies to minimize them. Artisans working in the informal sector, like those in Suame Magazine, often face additional challenges related to OHS practices. Due to the informal nature of their work, they may lack proper training, protective equipment, and access to healthcare. Investigating OHS practices in this setting can shed light on the unique vulnerabilities of these artisans and help implement appropriate interventions. By providing scientific evidence on the environmental contamination and occupational hazards associated with LAB recycling, this study will contribute to informing policy development and intervention strategies to mitigate the health risks and promote safer working conditions for these artisans. In addition, the results will provide evidence to support the World Health Organization's guidelines on the proper handling of used batteries made with lead acid. This highlights the immediate requirement for a national policy framework that includes regulations for the gathering, reuse and recycling, emission levels, and safety at work.

1.6 Scope of the Study

The study focused on collecting data from workers involved in artisanal LAB recycling at Suame Magazine in the Suame Municipal, Ashanti Region. Also, air and soil samples were collected in and around the LAB workshops.

1.7 Organization of the Report

The study is organized into six (6) chapters. Chapter one contains the introduction which dilates on the background to the study, statement of the problem, the purpose of the study, objectives of the study, research questions, significance of the study, delimitation, limitations, organization of the study, and definition of terms. Chapter two reviewed related literature which includes a theoretical framework and the review on major themes highlighted in the research questions (thematic areas). Chapter three takes a look at the methodology of the study which comprises research design and sampling techniques and procedure for collection of data and the techniques used in analyzing the data. Chapter four presents the results of the study. Chapter five a detailed discussion of the results. Chapter six presents the summary of the main findings of the study, conclusions, recommendations, and suggestions for further study.

CHAPTER TWO

LITERATURE REVIEW

2. 1 Ensuring Workplace Safety

Both employers and employees share responsibility for employee safety, although employers primarily hold the obligation for effectively managing workplace safety and health. The European Commission's 1989 Framework Directive (89/391/EEC) has empowered companies to examine dangers concerning occupational health and safety. This is due to the perception that employers are in the greatest position to recognize and manage workplace hazards since they oversee and understand the work processes (Hafner et al., 2015). Therefore, it is typically the responsibility of employers to guarantee that each worker's health and safety is safeguarded while they are at work (Famakin et al., 2012). According to Adu-Gyamfi, (2019) participating in risk management procedures at work is a crucial part of the employer's job description. Adeneyi (2010) defined a risk management system/process as a system that determines the OHS hazards that are pertinent to a workplace (Adu-Gyamfi, 2019). It entails recognizing dangers, evaluating risks, managing those risks, and documenting any mishaps. Employers have a responsibility to guarantee the safety and well-being of workers by safeguarding them against any possible health risks. Alfers (2012) defines safety hazards as workplace factors with the capacity to inflict substantial injury on employees. (Bentil, 2018). Employers who uphold social responsibility around the world consistently implement proactive health and safety measures before any hazards arise.

Nonetheless, some managers or companies only follow safety protocols after potential risks have been identified (Burton, 2010). According to Hughes and Ferrett, (2011), employers are responsible for ensuring the safe handling, storage, and use of goods, as well as providing sufficient first aid services. They must also notify employees about possible related to work dangers and give them with required information, instructions, training, and supervision to avert safety hazards. Employers must take measures to prevent or limit employees' exposure to harmful substances to maintain workplace safety. This includes providing the appropriate work equipment and ensuring that it is utilized and maintained appropriately. In addition, they must avoid potentially hazardous activities and take safety measures against dangers from electrical equipment, combustible or explosive materials, noise, and radiation (Adu-Gyamfi, 2019). Employers now bear a great deal of accountability for maintaining worker safety. Nonetheless, modern national strategies aimed at enhancing health and safety management place a strong emphasis on worker involvement in health and safety. Workers are better able to identify the causes of health hazards or accidents at work since they are the ones who are exposed to risks (Afsharian et al., 2018).

According to the 2011 European Agency for Safety and Health at Work, employee participation in health and safety issues is a two-way process. In order to make choices jointly, companies and their worker representatives must first communicate, listen to one another's worries, exchange information, and debate relevant topics. They also need to develop a relationship based on mutual respect and trust (Trevino & Nelson, 2021). In order to ensure workplace safety, workers must report any risks they see, operate safely and in accordance with safe work practices, and use the appropriate personal protective equipment (PPE) for the task (Shankar et al., 2022). Additionally, he or she is required to take part in workplace-specific health and safety programs. Each employee must ensure that they are secure and healthy by following the regulations and the secure working conditions -and procedures set by their company (Laflamme, 2015). It should be mentioned that employers are not only responsible for ensuring and implementing OHS standards at the workplace. Employee participation in management-or employer-sponsored training programs is necessary to provide safe workplaces. Employee and representative participation in safety-related making decisions is essential for ensuring safety at work (Murashov et al., 2011). The first paragraph of Article 13 of Directive 89/391/EEC of the European Economic Community states that each worker has the duty to prioritize their own safety and health, as well as the well-being of others affected by their actions or lack thereof at work. This responsibility should be carried out in line with the employee's training and guidelines provided by the employer (Adu-Gyamfi, 2019).

2.2 Lead-Acid Battery

2.2.1 Design and Electrochemistry

The lead-acid battery is the earliest and still a widely used power storage technology (Tang & Zhao, 2014). Lead acid batteries are used in various applications ranging from small-scale power storage like UPS systems to big grid-scale power systems, as well as in beginning lighting and ignition power sources for automobiles (Mandal et al., 2021). Lead-acid cells are cost-effective compared to other battery technologies, but they have poorer power density, heavier weight, and a shorter cycle life. Lead acid batteries have demonstrated significant improvements in cycle life with the incorporation of carbon onto the negative plate, either by directly adding it to the negatively active mass or utilizing it as an electrochemical supercapacitor (Chatterjee & Nandi, 2021). Carbon modification has rejuvenated the traditional lead-acid battery system, enabling its use in hybrid automobiles and static storage facilities. (Ali et al., 2021).

Figure 2.1 depicts the typical design of the majority of lead-acid batteries. The battery cell consists of positively charge plates made of lead-oxide (PbO_2) and negative plates made of a lead alloy, immersed in a solution of sulfuric acid. The liquid is usually composed of 35% sulfuric acid and 65% water. (Manhart & Schleicher, 2015). A non-conductive porous layer, usually constructed from a reinforced polyethylene grid, separates the cathodes and anodes (Manhart & Schleicher, 2015). The cathode plates are linked to the positive terminal, whereas the anode plates are connected to the negative terminal. Connectors and poles are primarily composed of lead (Manhart & Schleicher, 2015). The case is predominantly constructed from polypropylene. Lead acid batteries operate by the electrochemical transformation of lead and lead oxide into lead sulfate. The electrolyte, sulfuric acid, acts as both a reactant and an ionic transport medium in the battery (Enos, 2015).

2.2.2 Types of Lead-Acid Battery Designs

There are two primary Lead-acid battery models classified by the type of electrolyte they utilize. The conventional battery structure comprises both negative and positive plates submerged in a substantial quantity of electrolyte known as saturated lead acid (Zolin, 2017). The flooded architecture, while simple to manufacture and widely utilized in applications such as automobile SLI batteries, might encounter issues such electrolyte stratification and water loss due to evaporation. (Enos, 2015). The process of oxidation of lead sulfate to lead oxide is closely linked to the sulfuric acid concentration, rises as the concentration decreases (Enos, 2014).

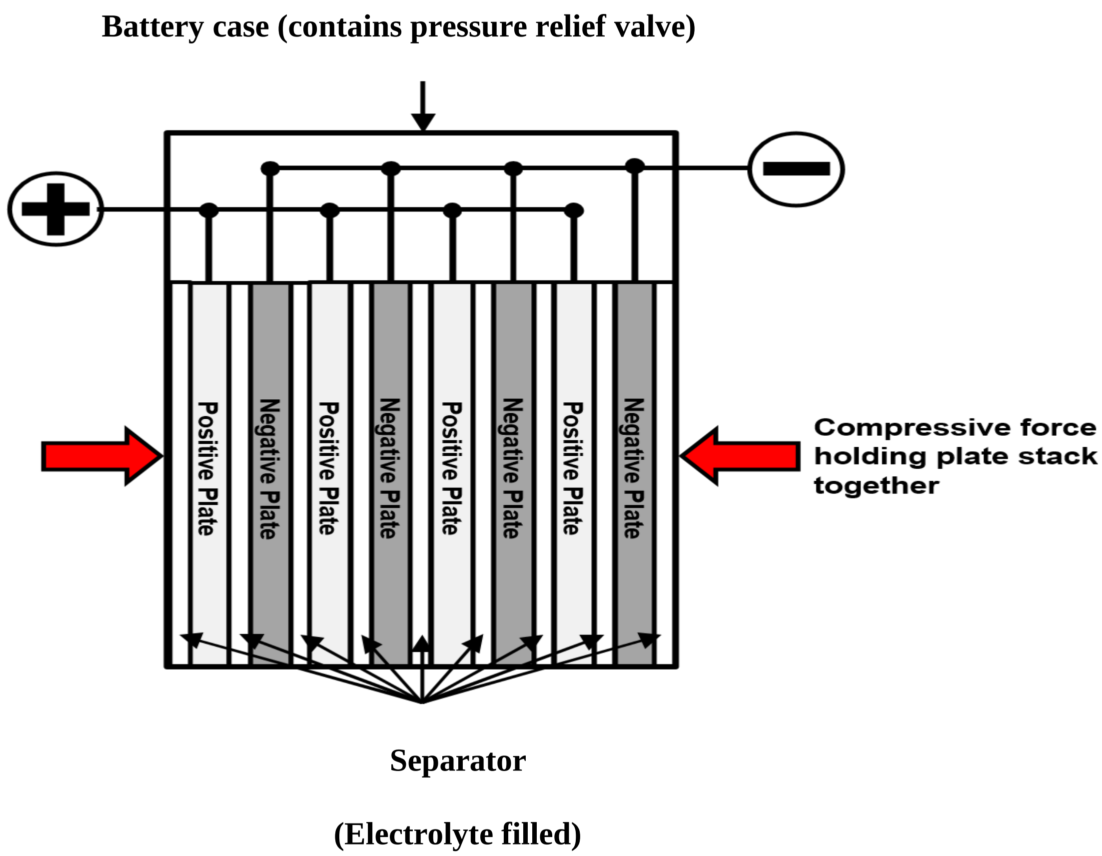

Figure 2.1: Diagram of a sealed Valve-Regulated Lead-Acid battery

(Source: Enos 2014)

The VRLA idea has numerous advantages in comparison to flooded battery solutions. The sealed design eliminates the need for watering systems and minimizes the safety and health hazards linked to vented batteries, such as acid spills, emission of acid vapors, and necessary ventilation due to gassing (Abbas et al., 2020). VRLA batteries can be used in any position, are easily carried, and have a lower size. Yet, the compact arrangement of standard VRLA batteries comes with drawbacks, including the necessity for precise heat management and extra charging conditions (Sims & Crase, 2017).

2.3 Factors Contributing to Work-Related Illnesses and Injuries

According to the International Labour Organization (ILO), some 2.2 million workers die each year as a result of illnesses related to work and injuries. 350,000 fatalities occur from accidents, meanwhile, the remaining cases are attributed to occupational ailments and ailments (Karlinsky & Kobak, 2021). Diverse viewpoints exist in the literature regarding the factors that lead to workplace accidents, injuries, and illnesses. Okafor & Okafor (2018) believe that accidents result from a collection of circumstances occurring simultaneously, rather than a single cause. Their belief is that a state with the potential to be dangerous does not result in a fatality unless someone comes into contact with it. Injuries arise due to hazardous environments, vulnerability, and human actions or behaviors (Shamsuddin et al., 2015). According to Stefanović et al. (2022), hearing loss and poor eyesight are significant factors linked to job injuries. A comprehensive examination of 1,347 workplace incidents and deaths determined that both personnel and management possess knowledge regarding safety issues and possible hazards.

The majority of workplace injuries occur due to management's lack of competence establish sufficient safety measures to safeguard workers from possible risks and harmful actions by workers. Workplace accidents leading to injuries are commonly caused by stress, primarily resulting from work demands (Kodom-Wiredu, 2019). A key factor contributing to workplace injuries resulting in fatalities and reduced working hours (Adu-Gyamfi, 2019). Referring to the American Institute of Stress Traumatic model, the author asserts that stress from work or other sources impacts an individual's job performance, leading to performance decline and work errors (Shakespeare et al., 2017). The error will result in accidents that may lead to harm or death. According to Mitchell (2021), the prevalence of stress, anxiety, depression, and neurosis conditions surpasses that of all other non-fatal injuries and illnesses related to work. There is a lack of comprehensive examination of the factors that contribute to workplace injuries across all levels of employment, including both formal and informal sectors.

2.4 A Comprehensive Examination of Workplace Health and Safety

Prior to the beginning of the 1990s, there was a lack of comprehensive understanding on the global effects of illnesses, injuries, and hazards in work environments (Collaborators, 2020). In 1991, the World Bank and the WHO started a worldwide Burden of Disease research to offer current statistics on the worldwide burden of occupational workplace injuries and diseases (Jacobsen, 2022). James et al. (2020) outlined crucial preventative methods for work-related illnesses and injuries in 187 countries using the worldwide cost diseases evaluations from 2010. Occupational illnesses and injuries have a substantial role in the global burden of diseases and injuries.

These illnesses have an impact on individuals, families, communities, countries, and the worldwide community, influencing global productivity. The projected cost of such incidents is inconsistent across the countries that record them. Some countries have GDP estimates ranging from approximately 2-14% (Adu-Gyamfi, 2019). The International Labour Organization (ILO) estimates it to be approximately 4% of the annual worldwide Gross Domestic Product (GDP) (Rantanen et al., 2020). Scholars and international organizations have expressed an avid curiosity in job-related injuries and sicknesses, presenting data on their rise and investigating strategies to reduce the incidence of industrial illnesses and injuries. It is essential to comprehend the causes, frequency, and geographical distribution of occupational diseases and injuries to effectively prevent them in various regions (Jilcha & Kitaw, 2016).

The WHO has played a significant role in informing the globe about the worldwide impact of work-related injuries and illnesses. The World Health Organization's Global Impact of Diseases project offers information on death and illness caused by more than 135 reasons for industrial illnesses and injuries. Additional literature on the assessment of similar risks has been generated, such as "The Global Health Risk Report" by WHO in 2009. The ILO (2005) says that around 2.2 million deaths occur each year due to occupational injury and sickness. Approximately 350,000 deaths are attributed only to fatal work injuries.

However, difficulties in disseminating information on important issues arise from inadequate data and varying reporting methods among countries, which hinders comparisons between nations (Traore et al., 2023). The studies offer useful data to guide subsequent studies on the present extent and magnitude of industrial diseases and injuries. However, they focus mostly on a broad perspective and do not give much attention to the specific details of local dynamics related to occupational injuries and illnesses. The current study investigates industrial injuries and illnesses in a developing country, focusing on both national and local contexts, particularly within the informal economy.

2.5 Characteristics and Categories of Workplace Health and Safety in Artisans

Automobile repair craftsmen are at increased risk of experiencing serious work-related injuries from piercings caused by vehicle accidents, leading to over 10 days of work absence (Adu-Gyamfi, 2019). Artists in automobile workshops commonly suffer from workplace accidents more than any other sort of harm. Heavy or demanding components such as combustion engines, radiators, gearboxes, transmissions, and mufflers can cause injuries when lifted. Prolonged work in uncomfortable positions can also lead to injuries. The present condition of physical damage tendency is common in all aspects of automotive repair, maintenance, and installation tasks, regardless of vehicle category (Salminen, 2023). Automotive repair and maintenance labor has a constant danger of severe injury or death due to its nature. Common hazards in car maintenance include vehicles dropping from lifts or jumping jacks, getting hit by cars passing while doing repairs on the side of the road, and tire explosions during inflation. Chronic exposure to fibers of asbestos or fumes from solvent and vehicle paint can be less noticeable and preventable, as mentioned by Adu-Gyamfi in (2019).

Managing industrial safety and health in Ghana Safety administration, as defined by Rantsatsi et al. (2020), encompasses a collection of procedures or protocols pertaining to the safety and well-being of employees in the workplace. The technique consists of three main responsibilities: Identification and assessment of potential dangers, protective measure planning, and regulation. Bravo et al. (2022), presented information indicating that certain workplaces experience a high frequency of injuries, while others with comparable tasks have either fewer or no reported injuries. Variations were identified in the implementation of safety and health measures at work practices among various places of employment. Workplace safety and health handling in Ghana is a crucial component of management according to Dwumfour-Asare & Asiedu (2013). Achievement necessitates leadership's unwavering commitment to the well-being and security of employees, their professional independence, the protection of their personal information, and transparent communication between management and staff.

Zhu et al. (2020), explain that OHS management entails supervising the social, physical, and emotional well-being of workers, along with their general health. A workforce's productivity is crucial for sustaining a society's material and financial framework. Ensuring the safety and health at work of workers is vital for productivity and plays a critical role in socio-economic and sustainable development (Adu-Gyamfi, 2019). At least seven percent of Ghana's GDP is spent on addressing issues related to the inadequate management of health and safety (Nyarko, 2021).

Monney et al. (2014) explain that it is important to emphasize that the protection of staff from job-related accidents and illnesses is a major issue for workers, employees, governments, and the general public population in Ghana during the last decades. An atmosphere that prioritizes safety in the workplace enhances the welfare of employees and mitigates expenses associated with work disruptions, healthcare costs, indemnities, and attrition of skilled personnel (Monney et al., 2014).

In Ghana, the regulations governing the oversight of employees' industrial safety and health at work are scattered. Dwumfour-Asare & Asiedu (2013) refer to the Labour Act 2003 (Act 651), the Factories, Offices and Shops Act 1970 (Act 328), and the Workmen's Compensation Law 1987 (PNDC Law 187). Implementing these laws faces many obstacles because to flaws in current legislation governing OHS management (Ametepeh, 2011). Lambert (2005) stated that efficient management of work environment safety can lead to increased productivity above the initial level seen (Adu-Gyamfi, 2019). This will ensure compliance with safety rules. Park (2018) found that businesses tend to adhere to health and safety rules after experiencing occupational injuries in previous years.

In Ghana, organizations like the Trades Union Congress aim to implement health and safety measures and create employee unions in order to enhance the working conditions for employees (Fartasch et al., 2012). These agencies usually protect employees who refuse to perform hazardous tasks and offer support and representation for workers involved in accidents compensation cases (Dartey et al., 2010).

2.6 Significance of Workplace Safety and Health

Employment yields financial and various advantages for the employee, their close relatives, and the community. Various occupational hazards pose dangers to the health and safety of workers (Salguero-Caparrós et al., 2020). This includes biological substances, chemical compounds, physical variables, poor ergonomics conditions, allergies, various safety risks, and a range of psychological and social risks. Mavroulidis et al. (2022), emphasize that occupational health and safety (OHS) concerns are a vital component of quality control, managing risks, and social responsibility as a whole for all firms. It is imperative that it is included as a fundamental element in all management growth initiatives. Studies indicate a correlation between improved employee health and functional capacity, heightened productivity, and decreased production expenses, hence advantageous for the organization.

Mensah (2021) proposed that the introduction of meticulously planned health initiatives in the work environment can yield enduring benefits in terms of employees' well-being and efficiency, ultimately resulting in heightened productivity. According to Asare (2021), creating a healthy and safe environment is advantageous for workers, businesses, governments, and the general public. According to Levy, Wegman, Baron, and Sokas (2011), Implementing strong occupational safety and health regulations can significantly reduce costs related to employee accidents and illnesses resulting from workplace hazards, including medical bills, sick leave, and disability payments. (Tanko et al.,2014).

The book "Safety Matters at Work" (2011) agrees and asserts that workplaces with effective communication and well-established safety programs can decrease injuries and illnesses, while also improving quality and production rates. A study conducted by Talati et al. (2020), found that companies might save a substantial amount by lowering the rate of obesity. Occupational wounds and ailments cause absenteeism and presenteeism, leading to decreased production and increased productivity costs (Nagata et al., 2018). Reducing occupational injuries can boost productivity, which is crucial for employers, particularly in countries with a scarcity of skilled labor (Kabaki, 2020). Employers will experience a decrease in pay losses and lower compensation costs given to employees due to workplace injuries (Kabaki, 2020). Efficient workplace safety management will decrease absenteeism and presenteeism, ultimately contributing to the retention of skilled labor. Afolabi et al. (2021a) asserts that effectively managing workplace safety is crucial for both the organization and its employees. Workplace safety is crucial for the company organization. According to (Massey, 2020) creating healthy work environments that prioritize both the physical and mental health of employees is essential for achieving corporate success. Tung, Chang, Ming, and Chao (2014) argue that workplace safety enhances worker health, productivity, social atmosphere, and operational efficiency.

2.7 The Recycling Process

The fundamental process of lead-acid battery recycling has been consistent for a considerable period. Used batteries are retrieved from the industrial sector through a reverse distribution system that includes businesses of all sizes, from major retailers to small garages. They are then returned to battery distributors/manufacturers or processed through car dismantling/scrap metal networks (Pourrahmani et al., 2022). The used batteries are taken to a recycling facility where they are subjected to pyro-metallurgical processes, typically to generate purified metals (Wagner-Wenz et al., 2023).

The lead-acid battery recycling process in nations lacking lead-refineries is often outlined in four stages, as depicted in Figure 2.2. Each one has an export pathway or option. Ghana offers all four export alternatives (Atiemo et al., 2016a).

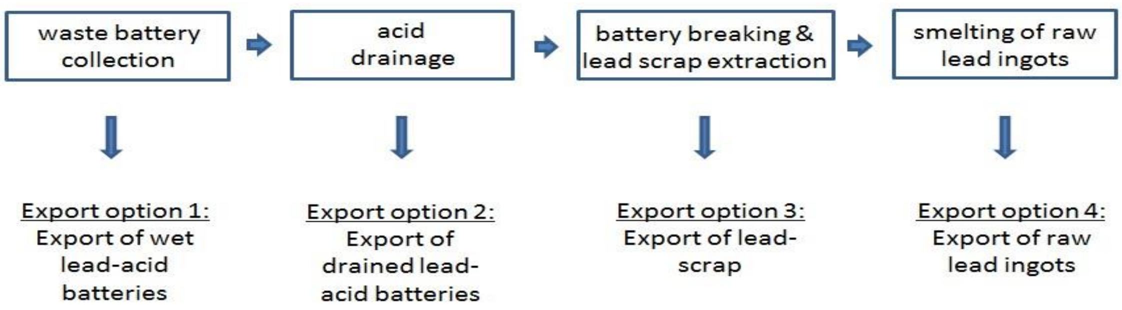

Figure 2.2: Lead-acid batteries battery management techniques for countries lacking lead refineries. Source: Oeko-Institute (2014)

Stage 1: Waste Battery Collection

Lead-acid batteries are economically feasible for recycling because of their high lead concentration. In the nation of Ghana, dealers and recycling organizations offer monetary compensation for the delivery of discarded lead-acid batteries (Manhart & Schleicher, 2015). Smaller and medium in size companies as well as people engage in collecting and marketing used lead-acid batteries for additional revenue (Manhart & Schleicher, 2015). Used batteries made of lead acid commonly gather in and around automotive repair shops and clubs.

Car-repair shops often keep recycled batteries from battery swapping services and give them to small-scale scrap metal collectors, referred to as 'scavengers,' merchants, or recycling companies, depending on the number of batteries collected (Atiemo et al., 2016b). The exports adhered to all international norms regarding packaging and notification. However, a country could potentially import wet lead acid batteries from neighboring countries (King et al., 2018).

Figure 2.3: Wet lead-acid batteries for export. Source: Oeko-Institute (2014)

Recovered batteries can be refurbished to produce and distribute functional pre-owned batteries in the nearby market. Reconditioning processes are typically carried out in small workshops with less emphasis on mitigating acid and lead emissions (Schroeder et al., 2019). Basic reconditioning involves replenishing the batteries with water/electrolyte and recharging them. Advanced reconditioning involves opening the casing and replacing failing cells. This form of reconditioning is generally believed to result in a relatively little enhancement of battery life (Haas *et al.*, 2021).

Stage 2: Acid drainage

People who gather and carry lead-acid batteries typically extract the acid by removing the plugs or creating holes in the casing before transportation. In the country of Ghana, the acid in batteries is commonly referred to as 'water' (Manhar et al, 2018). This is mostly done to decrease the battery's weight and since purchasers typically only compensate for discharged batteries or offer discounts for batteries that are not exhausted. Some batteries are exhausted before reaching trading centers, while others lose charge later in the administration process, as on metal scrap markets or in recycling battery plants (Kitila, 2018).

The uncontrolled acid drainage technique is the primary source of contamination. Acid emissions often release dissolved lead and lead particles, which have environmental and health implications. Some traders in Ghana export used batteries made with lead acid for recycling (Manhart & Schleicher, 2015). Previously, these cargoes were notified by the Ghanaian government. In 2013, authorities stopped providing warnings for exported batteries that were empty (Jang et al., 2022). It is uncertain if depleted batteries are shipped without warning.

Stage 3: Battery dismantling and lead scrap recovery

To recover the lead scrap, batteries are manually shattered with machetes. The procedure is mainly linked to significant releases of lead, lead-dust, and residual acid due to its common execution on unsealed surfaces without any preventive measures to minimize emissions (Ellis & Mirza, 2010). In addition to lead, the process also produces plastic casings that might potentially be recycled by nearby plastic companies. Open and empty battery cases suggest that battery breaking is being conducted in the region (refer to Figure 2.3). Some enterprises choose to export the recovered lead scrap to overseas lead smelters and refiners instead of sending it directly to smelting (Martins et al., 2021).

Figure 2.3: Opening of drained lead-acid batteries (Left) and Empty battery-cases (Right). Source: Oeko-Institute (2014)

Stage 4: Smelting raw lead ingots

The lead waste from battery cracking is often transformed into pure lead bars. This process is typically conducted in small backyard operations or large smelters equipped with industrial furnaces. Both processes produce unrefined lead ingots (Manhart & Schleicher, 2015). Industrial secondary lead melting can achieve purity of 97-99%, but ingots from backyard smelting include high quantities of lead-oxide. Both types of nuggets also include additional impurities including tin, antimony, for example and other metals (Humans, 2006).

In order to be used for the construction of new products (e.g. new lead-acid batteries), such ingots have to be delivered to refineries that can generate standardized lead with a purity of 99.97% (Manhart & Schleicher, 2015). While industrial lead-smelting can be carried-out without considerable emissions of lead, many poor standard facilities in underdeveloped countries and growing economies should be deemed essential in this regard. Industrial secondary lead smelting can be carried-out with many types of furnaces: blast furnaces, reverberatory furnaces, electric arc furnaces and rotary furnaces (Rascoff & Revesz, 2002).

The two most widely utilized types of furnaces - the blast and rotary furnaces. Both types of furnaces are powered by combustion materials such as charcoal. Within the furnaces, metallic lead is melted and lead-oxide is converted to elemental lead. Some contaminants might be eliminated with the slag-phase. The lead is casted into ingots, which are sent to lead refineries. Together with informal lead smelting, the process is ranked as the worst polluting activities in the world (Atiemo et al., 2016a).

Lead smelting requires no extremely high temperatures due to the relatively low melting point of lead at 327.46 °C (Manhart & Schleicher, 2015). The procedure is crucial due to its release of lead in solid form (such as dust) and lead fumes produced during smelting. In 2008, an unauthorized lead smelting activity in Dakar, Senegal, exposed 40,000 people to toxic lead particles and caused the demise of 18 children below five years old (Daniell *et al.,* 2015).

Figure 2.4: Backyard lead smelting. Source: Oeko-Institute (2014)

2.8 Release of Lead and Exposure During Recycling

During the gathering and shipping phase, the sulfuric acid that makes up the solution of electrolytes is sometimes extracted to reduce the weight of the batteries or because an additional fee is being paid for exhausted batteries (Mongusho, 2021). If the electrolyte is not removed at this stage, it may be discharged at the recycling facility. (In specific enclosed procedures, batteries are not emptied prior to being crushed). Electrolyte leakage from damaged batteries might occur during storage and transit (Meso, 2021). Failure to take sufficient care to prevent skin contact will result in caustic harm from the acid. If the electrolyte spills or is spilled on the ground instead of being collected, the lead it contains can mix with soil particles, leading to the creation of lead dust (Rees & Fuller, 2020). Disposing of the electrolytes in lakes or rivers will contaminate water that could be used for consumption, fishing, and culinary. Manual disintegration of batteries generates lead particles and lead oxide dust, posing a risk of lead exposure to workers (Ruiz Olivares, 2016). Dust and particles settle in the soil and can be carried by wind to distant locations, polluting the environment and posing a risk of exposure (Nordberg & Fowler, 2018). Hammermills and shredding machines have the potential to release lead mist, which can transform into lead dust when disturbed. The accumulation of dust on machinery that vibrates can result in its dispersion into the surrounding air, which can then be inhaled (Zhao, 2020). Water in automated separation systems becomes highly polluted with lead compounds during the separation process. Failure to address this issue before disposal may result in ground or soil contamination. Upon evaporation, water leaves behind a minute residue of lead dust that has the potential to be dispersed by the wind (UNEP, 2003).

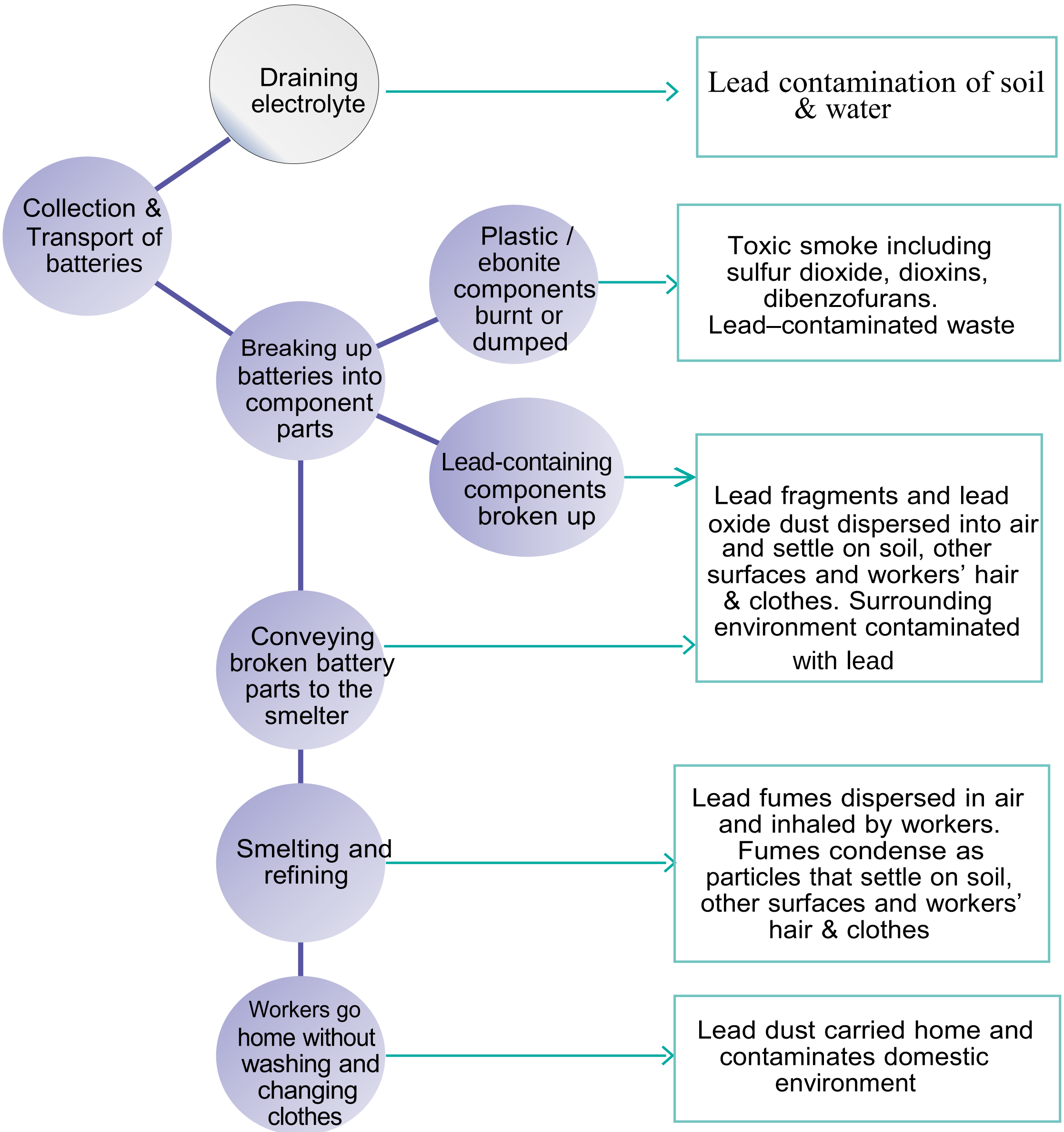

Figure 2.5: Locations where lead is emitted during the process of recycling batteries

Source: World Health Organization, WHO (2017).

Lead fragments and particles are emitted when lead components are moved throughout the recycling facility utilizing exposed transport chains or wheelbarrows, and when they are manually placed into the furnace. The process of lead refining requires the use of high temperatures, reaching up to 1000 °C, which leads to the generation of a substantial amount of lead fumes. Insufficient negative pressure in the furnace or inadequate ventilation and emission controls in the facility can result in workers inhaling the fumes (López *et al.*, 2023).

The high toxicity of lead fumes stems from their minute size of particles, which facilitates their inhalation into the lower respiratory tract and subsequent absorption (Ali et al., 2021). Over time, the gaseous substances will gradually come to rest as solid lead particles on objects in close proximity and the ground, creating lead dust that can be inhaled. The release of lead from these sources can be substantial and poses difficulties in terms of regulation. During the process of smelting, ash is sometimes manually sifted to gather metal particles, resulting in the release of dust polluted with lead into the atmosphere (World Health Organization, 2017).

During the recycling process, fumes, lead particles, and dust will adhere to the skin, hair, and garments of workers. If personnel neglect to cleanse themselves and change their attire before departing for their residences, they can expose household members and even the wider community to harmful substances (Rohlman *et al.,* 2022).

2.9 Awareness of Occupational Health and Safety Hazards

It is essential to implement health promotion measures at workplaces, especially among artisans, to establish a healthy work setting, particularly in poor countries where these initiatives are frequently neglected. Developed countries have established knowledge and rules for safety safeguards, however many underdeveloped countries lack these measures (Kumar *et al.,* 2016).

Addressing the lack of understanding regarding occupational dangers and safety practices among craftspeople is crucial, especially in developing nations (Balkhyour et al., 2019). Understanding occupational safety and health is crucial for preventing workplace accidents and illnesses (Van Dijk et al., 2015). It is crucial for all individuals exposed to occupational hazards to have a clear grasp of the risks they face in their workplaces. However, many workers lack awareness of potential dangers, which increases their susceptibility to injuries and illnesses (Yap & Lee, 2020).

Research has revealed that there are gaps in understanding regarding dangerous workplace exposures, and awareness levels vary significantly among different occupations and types of exposures (Vanka *et al.*, 2022). A number of studies have shown a significant level of awareness and understanding, whereas others have not. Certain individuals working in the informal sector possess a significant level of knowledge about occupational health hazards. Budhathoki et al. (2014) discovered that a heightened level of knowledge regarding workplace dangers and adherence to safety protocols existed among welders. In particular, 90.7% of welders were knowledgeable about at least one welding hazard. Osagiede et al. (2020) proposed that craftspeople, particularly welders, had greater knowledge of workplace hazards compared to safety measures and practices.

Diwe et al. (2016) conducted a study in South Eastern Nigeria that found a high degree of awareness of occupational hazards among forestry workers. This was attributed to the education level and work experience of the respondents. Tadesse et al. (2016) discovered a high awareness level (86.5%) of work dangers and their associated factors among welders. They concluded that awareness level was substantially linked to work experience, well-defined work regulation, job happiness, married status, and higher education. Okafoagu et al. (2017) found that nearly all participants in their study were familiar with Occupational Health and Safety (OHS). In a study conducted by Manuel et al. (2015) found that nearly all participants in their study were familiar with Occupational Health and Safety (OHS). Budhathoki *et al.* (2014) discovered that welders in Nigeria exhibited a lower level of expertise and awareness compared to earlier studies.

In Pakistan, Hassan et al. (2017) found that welders often lack awareness of the health risks and safety dangers related to their occupation. 45.7 percent of respondents in the study stated that they believe there is no significant health risk associated with the welding profession. Adu-Gyamfi (2019) discovered a disparity between the knowledge of occupational hazards (90%) regarding the use of personal safety gear (PPE) (47%) in the workplace. Onumbu & Elechi (2022) discovered a favorable correlation between the amount regarding the education and awareness of dangers among welders in Nepal, suggesting that awareness increases with greater education levels. Tadesse et al. (2016) discovered a substantial relationship between marital status and educational level and awareness of occupational dangers. Age was linked to awareness of occupational dangers among Indian sand and stone miners in a study by Ahmad (2017).

Adu-Gyamfi (2019) showed that awareness of occupational dangers among sawmill workers in Nigeria increased with age. The discrepancies in the study findings may be attributed to methodological variations, including differences in study population, definitions of hazard awareness, data collection methods, workplace conditions, and timing of the studies.

Understanding safety protocols Numerous studies have been undertaken worldwide about the awareness of safety practices. Marahatta et al. (2018) examined the awareness of occupational hazards and related factors among automotive repair artisans in Kathmandu Metropolitan City. The percentage of literate individuals who were aware of work hazards was discovered. Joseph et al. (2017) conducted a study to evaluate welders' knowledge of workplace dangers and their use of protective equipment. The cross-sectional study revealed a significant association between awareness of occupational health dangers and welding, with 62.6% of participants showing awareness. Syed et al. (2010) did research on welding and its related eye damage. Their awareness of safety precautions was deemed good.

The occupational hazards faced by auto-artisans in countries such as Nigeria, Zambia and India have been documented extensively. The research found a strong link between awareness and work experience, employment pattern, marital status, educational status, job satisfaction, safety training, supervision, and work regulation. (Magoolo, 2020) suggests that educational intervention is positively correlated with knowledge and utilization of personal protective equipment (PPE). The research examining the impact of instructional interventions on understanding and utilization of Personal Protective Equipment (PPE) found that 97.9 percent of artisans recognized a favorable influence on their awareness of wearing eye goggles for protection. Adu-Gyamfi (2019) found that 78% of artisans surveyed were unaware of protective eye protection during work.

2.10 The Public Health Impacts of Lead Exposure

Lead exposure has two main effects on the population: it impairs the neuropsychological development of kids as well as increases the risk of cardiovascular disease in adults. Children have an elevated risk of reduced cognitive ability, IQ, attention, visual-motor skills, reasoning skills, and social conduct, which ultimately results in a greater burden on public health and the economy. Lead poisoning has a notable effect on the intelligence quotient (IQ) of children at a population level, even though the estimated decrease is only 6.9 points within the blood concentration spanning 2.4 to 30 µg/dL (Bellinger, 2012). A projected decline in the average IQ from 100 to 97 would lead to an 8% increase in the number of people with an intelligence level under 100 and a 57% increase in the number of people with an IQ below 70, which is generally considered the cutoff for identifying intellectual impairment. There would also be a 40% reduction in the number of individuals who are high-achieving and have an intelligence rating above 130 (World Health Organization, 2017).

Healey et al. (2010) A study conducted on the Canadian population revealed that a rise in levels of lead in the blood from 1 µg/dL to 4 µg/dL in adults is associated with an average increase in systolic blood pressure of around 0.8 mmHg (0.11 kPa) in Caucasian males and 1.4 mmHg (0.19 kPa) in vulnerable subgroups. While the impact on individuals may be small, increases in blood pressure are associated with age-specific elevated death rates for both ischemic heart attack and strokes (Andraweera et al., 2021). In 2015, lead exposure was predicted to contribute to 12.4% of the worldwide burden of idiopathic intellectual disability, 2.5% of the global burden of ischemic heart disease, and 2.4% of the global burden of stroke (Barinova et al., 2020).

2.11 The use of Protective Personal Equipment at Workplace

Utilizing and implementing PPE is essential for reducing the risk of occupational accidents and health issues. (Afolabi, de Beer, & Haafkens, 2021b). Multiple studies have been carried out about the utilization and acceptance of PPE. While some data showed little utilization of PPE, others indicated a significant level of PPE usage. In a survey conducted in Uganda conducted by Rafindadi et al. (2022), just 15.6% of the respondents utilized Personal Protective Equipment (PPE).

Johnson & Motilewa (2016) also noted a low level of utilization in Nigeria. 27.8% of the respondents used personal protective equipment (PPE), with overalls being the most commonly used type at 78.8%. Marahatta et al. (2018) investigated the level of knowledge regarding work-related risks and associated concerns amongst automobile maintenance artisans in Kathmandu Metropolis City. 44.3% of artisans were seen to be utilizing Personal Protective Equipment (PPE). Khadka et al. (2021) found similar results in Nepal when investigating the level consciousness of job hazards and the use of safety precautions among artisans. Out of the respondents, 34.2% reported using protection items. The most frequently utilized devices were spectacles (60.9%), rubber gloves (50.3%), and footwear (34.5%). Skilled craftsmen in Dares Salaam, Tanzania, who operate in welding, spray painting, and metal work, demonstrated minimal utilization of Personal Protective Equipment (PPE) according to Langat (2020). Joseph et al. (2017) in Port Harcourt, it was observed that just 15.3% of welders used glasses to protect their eyes.

In Ghana, Monney et al. (2014) found that Only 27% of the craftspeople in Mampong-Ashanti were seen utilizing Personal Protective Equipment (PPE) during their job. In addition, a study conducted in Kumasi to evaluate perceptions of occupational chemical dangers, safety practices, and enforcement found that only 0.7 percent of respondents consistently used proper Personal Protective Equipment (PPE) when spray painting (Adei et al., 2011).

In Nigeria, Abraham et al. (2015) discovered that 87.2% of the ninety-five participants were not using any eye protection at work. Some research indicated a high level of utilization of personal protective equipment (PPE). Tetteh et al. (2020) Discovered that 86% of fabricators employed protective eyewear. Hassan et al. (2017) discovered that 95.7% of the welders in India used at least one protective measure in the week prior to the study.in a study conducted by Megbele et al. (2012) it was discovered that 60% of Nigerian metal arc welders wore eye protection equipment, while examining the risks of cataract.

2.12 Management of Workplace Safety and Health in Ghana

Management of safety, as defined by Benjaoran & Bhokha (2010) encompasses a series of measures or protocols concerning safety and health within a work environment. The process consists of three main tasks: hazard detection, safety measure planning, and control.

In Ghana, occupational health and safety management is considered a fundamental aspect of management (Adu-Gyamfi, 2019). Success requires management dedication to health and safety, professional autonomy, privacy, and collaboration between management and employees. Quansah (2008) defines OHS management as the management of the emotional, social, and physical well-being of workers, encompassing the overall individual. A labor force's working capacity maintains the material and economic foundation of a society.

Occupational health and safety of workers are essential requirements for productivity and play a crucial role in socio-economic growth and sustainability (Adu-Gyamfi, 2019). Ghana allocates a minimum of 7% of its gross domestic product to tackle problems associated with insufficient health and safety management (Nyarko & Simons, 2021).

Adu-Gyamfi (2019), highlighted that ensuring the well-being and protection of workers from occupational accidents and illnesses have been prioritized a significant concern for workers, employees, governments, and the general population in Ghana throughout the previous decades. A safe working environment promotes the well-being of workers and reduces costs related to work interruptions, medical expenses, compensation, and losses. In Ghana, legislation concerning the management of employees' Occupational Health and Safety (OHS) at the workplace are disjointed.

2.13 Artisanal Workers' Knowledge and Understanding of Occupational Safety and Health Practices

Numerous studies have been undertaken globally about the consciousness of safety protocols. Located in Nepal, Marahatta *et al.* (2018) researched the understanding of work dangers and associated factors amongst automobile maintenance workers in Kathmandu Metropolitan City. 56 percent of individuals who were knowledgeable about work hazards were literate. In a study by Joseph et al. (2017), awareness of work dangers and utilization patterns of protective equipment amongst welders was assessed.

The cross-sectional study revealed a significant association between awareness of occupational health dangers and welding, with 62.6% of participants showing awareness. Adu-Gyamfi (2019) did research on welding and the eye problems it causes. It was disclosed that their understanding of safety protocols was adequate.

The dangers faced by auto-artisans are well-recognized in countries such as Nigeria, Zambia, and India. Anlimah et al. (2023) suggest that educational intervention is positively correlated with awareness and utilization of PPE. The survey showed that 97.9% of craftsmen reported a positive impact on their awareness of using eye goggles for safety due to the educational intervention. Adu-Gyamfi, (2019) found that 78% of artisans surveyed were unaware of protective eye protection during work.

2.14 Factors in the Workplace That Influence Occupational Health and Safety

The research characterized the job-related state as the health and safety situations in the vehicle repair workshop associated with exposure to lead. Workplace safety and health focus on implementing methods and protocols to reduce or prevent workplace accidents and limit exposure to biological and chemical risks. Key environmental issues at automotive workshops may include ensuring proper cleaning, lighting, ventilation, water drainage, and sanitation and water supply. (Ghaffarianhoseini *et al.*, 2018).

Effective ventilation is essential in atmospheric studies and automobile repair facilities to control the release of fumes and dust generated during repair procedures, especially in enclosed areas. It aids in supplying clean air for respiration and shields the inhabitants from inhaling pollutants. The Kenya Occupational Safety and Health Act of 2007 highlights the significance of maintaining a hygienic work environment to protect the well-being and safety of workers. Maintaining a secure and hygienic setting is crucial in order to prevent workplace accidents and minimize the risk of ingesting or inhaling harmful substances. Regular maintenance of workplaces, devices, and gadgets is necessary to maintain proper workplace hygiene (Odongo, 2019). The worker's operational context has a substantial influence on the safety and health protocols in an automotive repair enterprise. Numerous unofficial vehicle repair workshops lack sufficient conditions for operation and function outdoors. Odongo, (2019) stated that the majority of informal sector workers in Ghana work in temporary huts under trees or in open places, a situation similar to that in Kenya.

Most workshops have adequate ventilation and lighting, but, they are often disorganized and do not have toilets or other hygienic amenities (Odongo, 2019). Workplaces are required to provide appropriate washing facilities as well as sufficient sanitary facilities for workers. These conveniences have to be well-maintained and kept tidy (Odongo, 2019). Workplace overcrowding, especially in areas with machinery and equipment and exposure to health dangers such air pollutants, might heighten the likelihood of accidents and occupational illnesses (Langat, 2020). The Kenya-OSH Act 2007 states A tenant must guarantee that the work environment is not excessively crowded to the point where it presents a risk of harm to the worker's well-being. By implementing these practices in the workplace, the occupational lead risks for automobile maintenance artisans can be reduced.

Regulating the informal automotive repair business is difficult due to its unstructured nature. The workers in the industry lack awareness of workplace safety issues or are unable to purchase protective equipment to shield them from harmful environmental and occupational circumstances (Amfo-Otu & Agyemang, 2017). Automobile workshops can pose significant risks due to several hazards such as dust, fumes, chemical vapors, and cuts. Ametepeh et al. (2013) found that informal sector workers in the Sekondi-Takoradi metropolitan area in Ghana faced various occupational health hazards, including chemical hazards Physical dangers, such as smoke, dust, and fumes, as well as disturbances, fire, and a dirty atmosphere, all pose risks. Ergonomic threats, such as poor working position, and psychological hazards, such as stress and violence, can also be detrimental. These hazards can result in either acute or long-term sickness, as well as fatalities in humans. Working procedures, managerial controls, controls for engineering, as well as PPEs are commonly used to protect workers from occupational hazards by implementing hazard control principles (Jilcha & Kitaw, 2016).

Risk management methods should be implemented in a tiered fashion, prioritizing controlling the danger at its source. The priorities include eliminating risks in the work environment, substituting hazardous materials, equipment, or processes with safer alternatives when elimination is not possible, implementing engineering controls to isolate and protect individuals from hazards, and utilizing administrative controls such as implementing educational programmes, providing training, and implementing work rotations to minimise the likelihood of encountering hazards. Personal protective equipment (PPE) is the least prioritized control measure according to Nalugya et al., (2022).

High priority control measures are seldom enforced in informal work environments due to insufficient resources and limited technical expertise regarding OSH regulations

(Kumie *et al.,* 2016). Additionally, the industry is affected by inadequate or absent occupational safety and health legislation and services.

This may be accomplished by employing a partial confinement, such as a ventilated bench, or by positioning hoods in close proximity to the source of emissions (McManus & Haddad, 2015). The respirators might be employed to control and mitigate contact with fumes and gases. These controls give specific information on the composition of the product, instructions for usage, hazard cautions, and emergency response protocols. Product labels are frequently disregarded because of a limited comprehension of the health and safety hazards associated with the items (Adei et al., 2011).

By implementing substitution techniques, such as the application of solder that does not include lead in the process of welding processes, the likelihood of encountering dangerous substances can be reduced, particularly in terms of minimising exposure to lead. Education on secure work methods, equipment usage, and procedures is a proactive way to mitigate Work-related health risks. Employing proactive methods such as regular air inspecting and occasional medical examinations for employees can effectively mitigate the consequences of occupational hazards. According to Section XI of the Kenya-OSH Act, 2007, it is recommended that workers get regular medical check-ups, especially if they have illnesses that may be attributed to their employment procedures and circumstances. Research has indicated that those employed in informal firms are at a heightened risk of encountering occupational dangers and facing uncertainty (Oche et al., 2020).

Artisans in vehicle repair workshops should utilize appropriate Personal Protective Equipment (PPE) to avoid potential dangers and associated negative health consequences (Apreko et al., 2015). Personal protection equipment (PPE) is worn to protect individuals against physical, chemical, and biological threats in the workplace. The effectiveness of these Personal Protective Equipments (PPEs) relies on the workers' proper use, understanding, and willingness to utilize them. They must be chosen meticulously to adequately safeguard workers from occupational dangers (Russo, 2015). Personal Protective Equipment (PPE) such protective clothes, respirators, and eye and ear protection can be beneficial.

They must be used in conjunction secure work procedures and control systems for engineering, get optimal outcomes. The necessary protective equipment for vehicle repair includes gloves, headgear, a work apron, a face shield, protective clothing, eye protection, and helmets. Utilise earmuffs or ear plugs as a means of safeguarding your auditory system when engaging in noisy tasks.

Okwabi et al. (2016) In their study on evaluating safety awareness amongst employees in informal sector garages in Accra, Ghana, researchers discovered that a mere 12% of participants utilised PPE. Furthermore, it was found that none of the participants had undergone any form of instruction or education on personal safety or the proper utilisation of PPE. This lack of training deprives them of the necessary knowledge and abilities to recognise potential dangers within the workshop environment. In a separate investigation carried out in a casual applying spray paint workshop, a mere 0.7% of participants consistently employed the essential PPE, include aprons, respirators, safety glasses, and protective footwear, in order to mitigate workplace dangers, such as breathing in harmful fumes and fine droplets throughout the spray-painting process (Adei et al., 2011). Rongo et al. (2004) found that workers in Dar es Salaam, Tanzania's small-scale companies were exposed to several occupational hazards but failed to utilise protective gear.

Sambo et al. (2012) found that roadside automotive mechanics in Zaria, North Western Nigeria, were well-informed about occupational health dangers but did not use protective devices frequently. According to Awiti et al. (2019) he the casual sector in Kenya employs over 80% of the nation's employed individuals. This figure could indicate the prevalence of workers exposed to perilous workplace circumstances, such as an unstable job and inadequate social and labour safeguards.

Ensuring safety and promoting good health in workshop environment practices are crucial in informal sector companies to avoid or minimize workplace diseases. Research must be carried out on labor, the objective is to provide health and social protection measures for the informal auto repair sector by examining its circumstances and practices. Moreover, there is a lack of information regarding the established protocols for craftsmen in the industry, as stated by Jerie (2016). These personnel are susceptible to a range of health hazards as a result of their work environment to the nature of their repair work operations. This study aims to increase awareness and improve the creation of health and safety measures and awareness programs for vehicle repair artisans.

CHAPTER THREE

MATERIALS AND METHOD

3.1 Study Sites and Location

The study was conducted in LAB workshops in Suame Magazine, located in the Suame Municipality of the Ashanti region. Suame Magazine is an industrial zone in Ghana that houses numerous businesses specializing in metal engineering and auto maintenance, employing around 200,000 persons. The Suame constituency in Ghana is situated 10 km away from the central business district of Kumasi, the capital of the Ashanti region. It falls within the administrative district of the Suame Municipal Assembly (SMA). It is the most industrialized area in Ghana and one of the greatest industrialized areas in Africa. Figure 3.1 displays the study site and sampling locations inside the industrial zone.

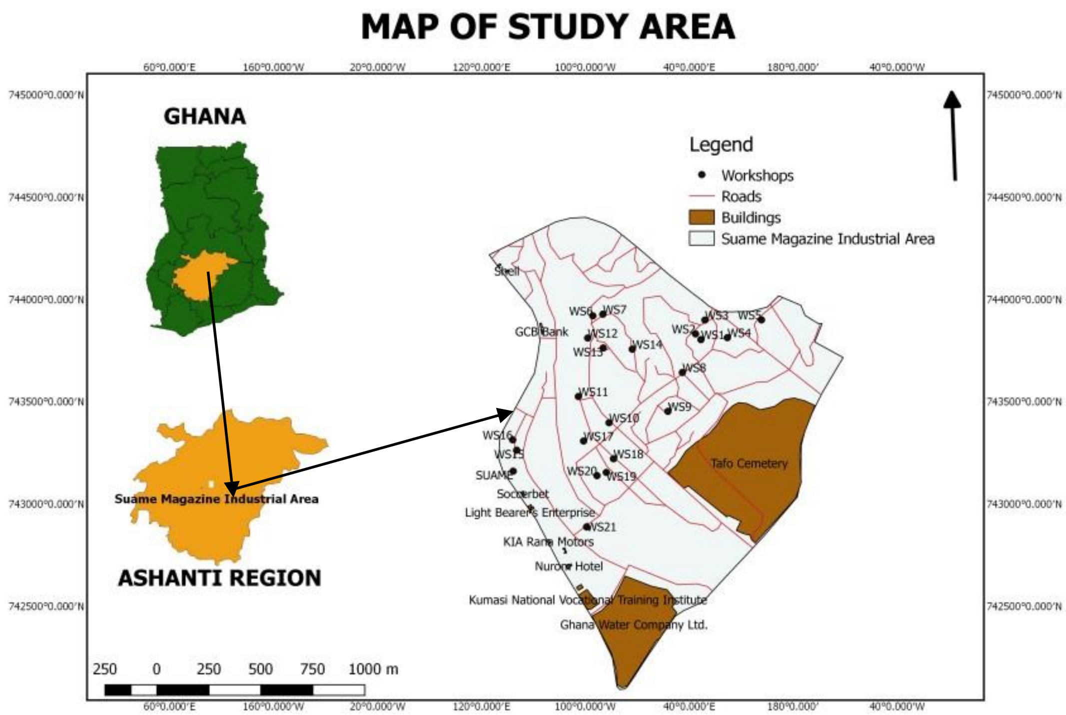

Figure 3.1: Suame Magazine Industrial area

3.2 Study Design

A cross-sectional design was employed for this study by using questionnaires to assess artisans' knowledge of Occupational Health and Safety practices and working practices, such as washing of hands after working on batteries, wearing of nose masks, safety boats, hand gloves and overall coats at the workplace. Data was gathered from participants at the study sites using structured questionnaires. The study focused on workplace exposure assessment by applying the following approaches (i) determination of Pb concentration in soil and estimating occupational exposure using mathematical models. Measurement of Pb levels in Airborne particulate thus an assessment of the levels of lead both in soil and airborne particulate and its impact on the artisans.

3.3 Sampling of Workshops and Participants

There were about 35 LAB workshops at the study area but 21 were selected using the snowball sampling technique. This technique helped to locate other workshops in the study area with the help of other respondents. The workers (1 or 2) from each workshop responded to the questionnaires for the qualitative aspect of the study.

3.4 Soil Sampling and Preparation

Twenty-one soil samples each were collected from the inside and outside of the LAB workshops, samples picked inside the shop were coded; (ASA1 to ASA 21) and that of samples picked outside the workshops were also coded (ASB1-ASB21). The samples were picked at the exact spots where the artisans worked on the LAB recycling and at their resting places up to a depth of 4 cm using a stainless-steel garden shovel and fork into labelled zip lock bag for analysis (Laidlaw et al., 2017). The soil was air-dried in the laboratory for a week, further ground into fine particles using a mortar and pestle and passed through a 0.2 μm sieve for laboratory analysis.

3.5 Air Sampling

The sampling and preparation of air particulates were based on the air pollutant monitoring and analysis protocol for developing countries Gulia, Khanna, Shukla, and Khare (2020) coupled with a modified method for sampling air particulates according to Dartey *et al*. (2016). At the same points where the soil samples were collected, airborne particulates were also sampled at a height of 1.5 m using the filter membrane technique described by Gulia et al. (2020). Airborne samples from the LAB workshop were collected using 25 mm total dust air sampling cassettes (Millipore, Bedford, MA, USA) equipped with 5 μm cellulose nitrate membrane filters (Liao, 2021). Air sampling was performed with SKC sidekick pumps (SKC Ltd. Dorset, UK) operated at a flow rate of 2.0 ± 0.1 L/min (Thomassen, 2016). The sampling time was approximately 6 hours. The airflow was measured at the beginning and at the end of the sampling period. A nitrocellulose membrane containing 15% HNO_3 was used to collect dust particles. The collection of these air-borne particulates was done using samplers set inside the workshops during normal day activities of LAB recycling workers (Gulia et al., 2020).

3.5 Sample Digestion and Lead Analysis

A gram of each sample was measured in a labelled digestion tube. Quantities of 10 mL of nitric acid (HNO_3), 3 mL of perchloric acid ($HClO_4$) and 3 mL of sulphuric acid (H_2SO_4) were added to the measured samples. The digestion tubes were then swirled to mix and dissolve the samples. A blank was prepared by adding 10 mL HNO_3, 3 mL H_2SO_4 and 3 mL $HClO_4$ into a labelled digestion tube (da Silva et al., 2014).

The digestion tubes were placed into digestion blocks heated to 200 ^{o}C for about 30 minutes with continuous monitoring of the temperature with a thermometer. After about 30 minutes into digestion, 5 mL of nitric acid was then added to each digestion tube. The heating continued until digestion was completed and a clear digest was observed. Digests were left to cool down, filtered with a Whatman No.4 filter paper topped up with deionized water to a final volume of 50 mL and transferred into 50 mL falcon tubes for analysis (da Silva et al., 2014).

The concentrations of Pb were determined with an Agilent Model 240FF Atomic Absorption Spectrophotometer (AAS) manufactured by Hitachi High-Tech Corporation. at the Council for Scientific and Industrial Research-Soil Research Institute (CSIR-SRI), Kwadaso-Kumasi, in the Ashanti Region of Ghana was used for the laboratory work.

3.6 Quality Assurance

Stringent measures were implemented to ensure the accuracy and reliability of the study findings. The analysis involved using high-quality chemicals (such as nitric acid, perchloric acid and sulphuric acid) of analytical grade and deionized water for sample digestion (Yang et al., 2023). Glasswares underwent thorough washing and cleaning procedures using deionized water. Moreover, blank solutions were prepared and analyzed for the soil and air samples. Standard solutions of the respective elements were employed to establish calibration curves, which aided in configuring the instrument settings for precise analysis (Isaguirre et al., 2020). The detection limits were determined based on the slope and standard deviation of these calibration curves. Ten samples were subjected to duplicate analyses to evaluate the reproducibility of the results (García-González et al., 2023).

3.7 Data Analysis

Microsoft Excel and SPSS statistical tool developed by IBM an American International Company were employed for the analysis of data collected on air and soil samples at the various sites. A single-factor analysis of variance (One-way ANOVA) was conducted to ascertain the level of variation in concentration of Pb.

3.8 Health Risk Assessment

Pb is a toxic element hence, a health risk assessment provides information on the impact of Pb from particulate emissions, dust and soil from the study area on the working population. The risk assessment was conducted for adults and children since the Suame magazine industrial area is largely made up of adult workers and some petty traders which includes children. Significant routes of exposure to Pb toxicity are via dermal and inhalation routes. Carcinogenic and non-carcinogenic risk assessments were conducted according to the risk assessment guide by the United States Environmental Protection Agency (USEPA) on human exposure to potentially toxic elements in contaminated soil (USEPA, 1997). A cancer risk (CR) value of greater than the maximum limit of a 10^{-4} to 10^{-6} range and a hazard quotient (HQ) value of ≥ 1 suggests the likelihood of the contaminant resulting in adverse health effects to the exposed population (USEPA, 2011). Risk assessment through inhalation was calculated for using Equations (2) to (4) (Lau, Liang *et al.*, 2014);

$ADDinh = Cinh \times (inhR \times ED \times EF)/(PEF \times BW \times AT)$………………Equation (2)

$HQ = \frac{ADDinh}{Rfdinh} \ldots\ldots\ldots\ldots\ldots. Equation\ 3$

$$\frac{CRinh}{derm} = \frac{ADDinh}{derm}\ x\ \frac{SFinh}{derm} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Equation\ 4$$

$\frac{ADDinh}{derm}$= Average daily dose through inhalation or dermal contact

Rfdinh= Chronic reference dose through inhalation

SFinh= Cancer slope factor through inhalation

Cm= Concentration of metal in soil/air particulate

CR= Cancer risk

Crinh = Cancer risk through inhalation

Derm = dermal

Risk assessment by dermal contact was also calculated for employing Equations (5) and (6) (Lau et al., 2014);

$CDI = \frac{Cm \times SA \times AF \times ABSd \times EF \times ED}{W \times AT \times L}$…………………………Equation (5)

$HQ = \frac{CDIderm}{Rfdderm}$…………………………………Equation (6)

Where, CDI = Chronic daily intake

Rfd = Chronic Reference dose

Table 3.1: Characterization of risk assessment

Parameters	Definition	Values (Adults)	References
inhR (m^3/day)	Soil inhalation rate	20	USEPA, (2002)
ED (year)	Exposure duration	24	
EF (day/year)	Exposure frequency	350	
PEF (m^3/day)	Particulate emission factor from soil to air	1.36×10^{9}	
BW (kg)	Average body weight	70	Wang *et al*., (2020)
AT (day)	Average time	365×ED	
RfD (mg/kg/day)	Reference dose (inhalation)	Pb= 3.5×10^{-2}	
SF (mg/kg/day)	Cancer slope factor	Pb= 4.2×10^{-2}	
SA (cm^2)	Exposed skin area	5700	Luo *et al.*, (2012)
AF (mg/ cm^2)	Soil-to-skin adherence factor	0.07	
ABS_{dermal}	Dermal absorption factor	1×10^{-3}	
L	Unit Conversion factor	10^{-6}	
RfD_{dermal}	Reference dose (dermal)	3.5×10^{-3}	USDOE, (2011)

CHAPTER FOUR

RESULTS

4.1 Socio-Demographic Data of Respondents

Information on the gender of respondents revealed all twenty-one respondents were males. The age range of the respondents ranged from 22 – 52 years. The highest frequency (7) occurred for respondents within the age ranges of 31-40 and 41-50.

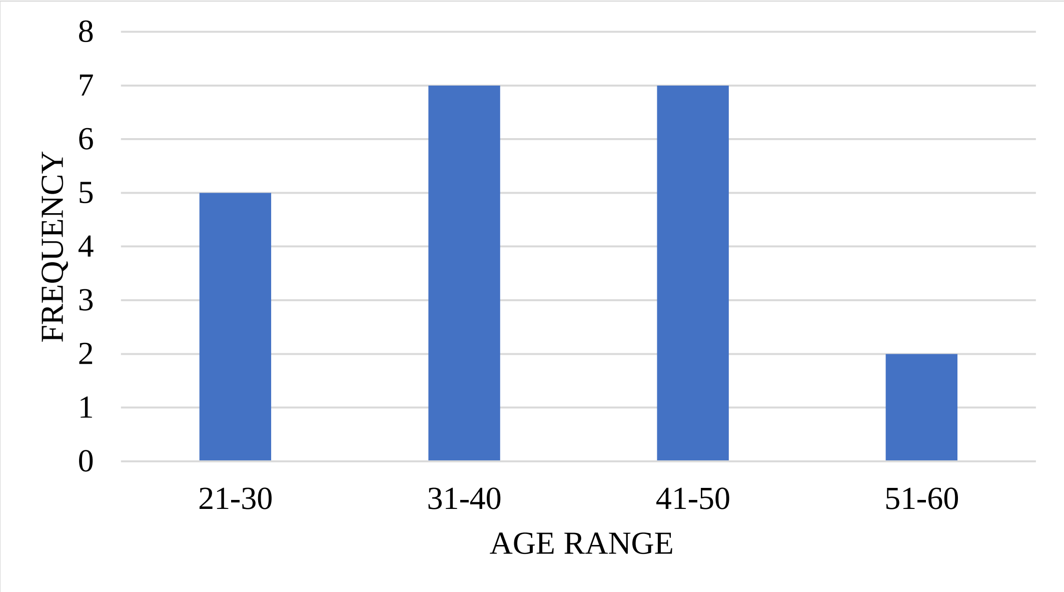

Figure 4.1: Age range of LAB recyclers

Survey on educational background of respondents in this study revealed just 4.8% had tertiary education. LAB recyclers with a pre-tertiary educational background constituted 52.4% in this study.

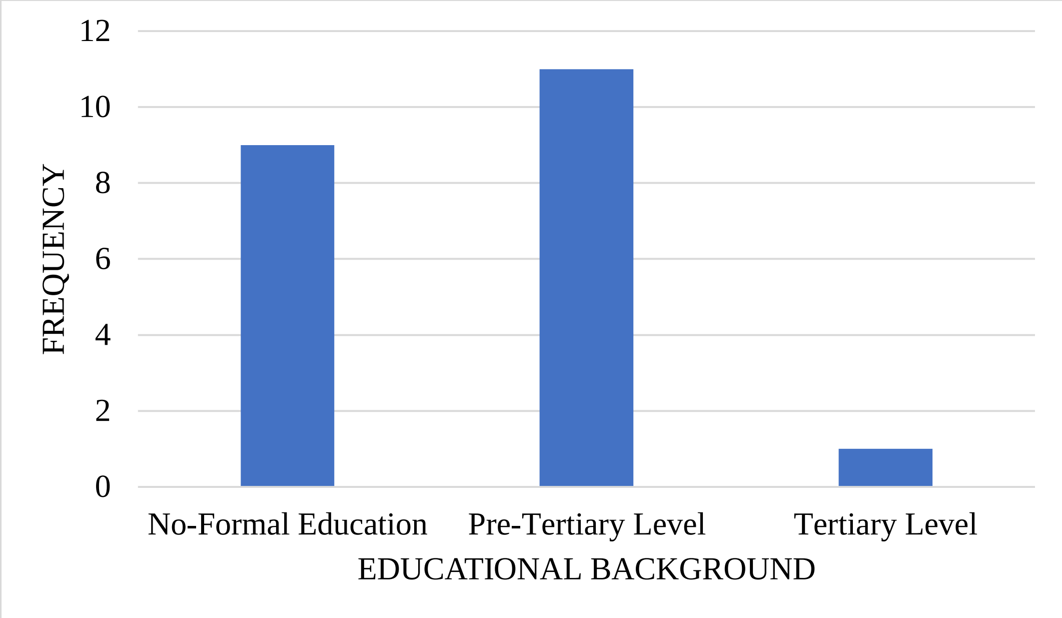

Figure 4.2: Educational background of LAB recyclers

In this study, Suame Magazine LAB recyclers' work experience ranged between 2 to 33 years. Recyclers with 11-20 years of experience represented 47.6%, where as 4.8% represented recyclers with 31-40years of work experience.

Figure 4.3: Respondents' years of experience with LAB recycling

4.2 Safety Practices of LAB Recyclers at Suame Magazine

Recyclers' contact duration with LABs was reported to be between 15 minutes to as far as 90 minutes per day. The highest frequency occurred for 30 minutes of contact duration followed by 60 and 70 minutes. Recyclers with contact duration of 90 minutes represented 14.3%.

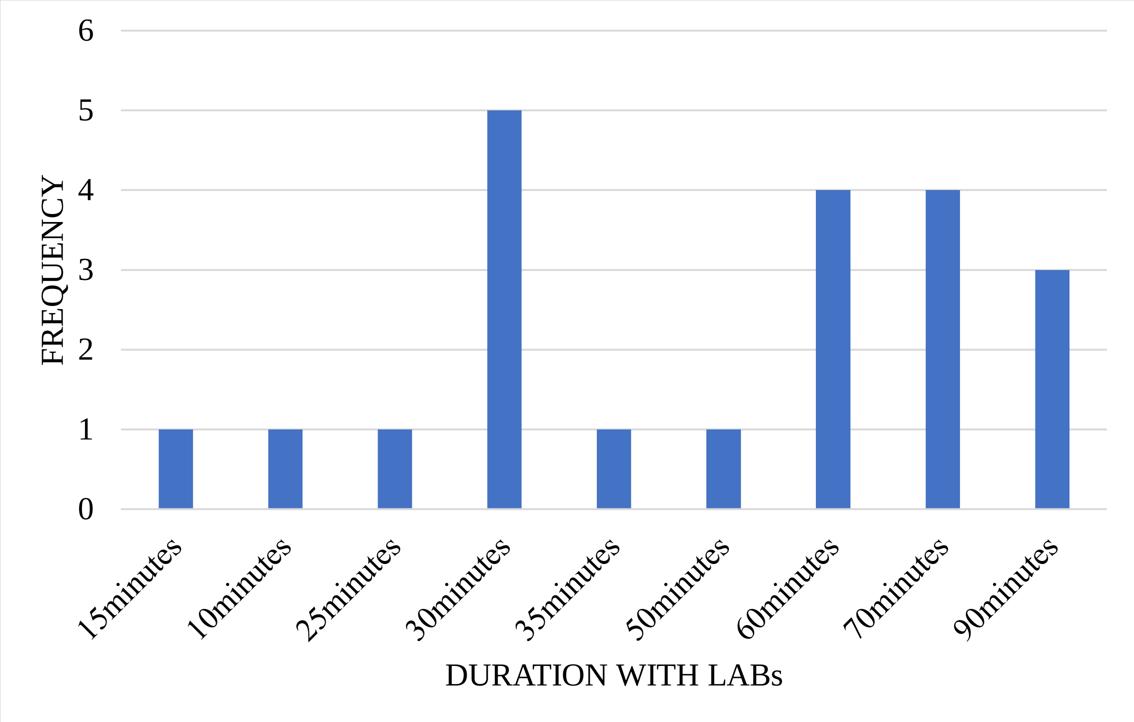

Figure 4.4: LAB recyclers at Suame Magazine's per day contact duration with LABs

From this study, stained hands of recyclers were kept cleaned either by the use of soap, washing powder or just water. The use of soap and water predominated the method for stain removal from hands, followed by the use of washing powder then just the use of water. Recyclers that used just water for removal of stains on hands represented 14.3%.

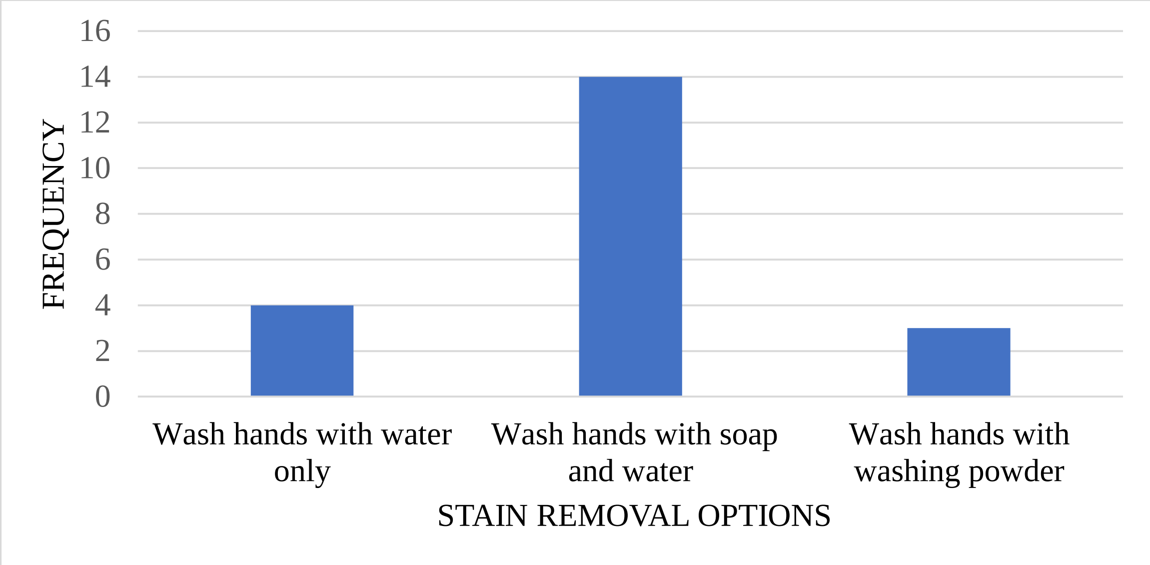

Figure 4.5: Method of removal of stains on hands among LAB recyclers

Response on place of washing of working gear by Lab recyclers informed of two main spots; the workshop and at their place of residence. Washing of working gears at workshops was carried out by 85.7% of respondents. There were recyclers that washed both at their workshops and at their place of residence.

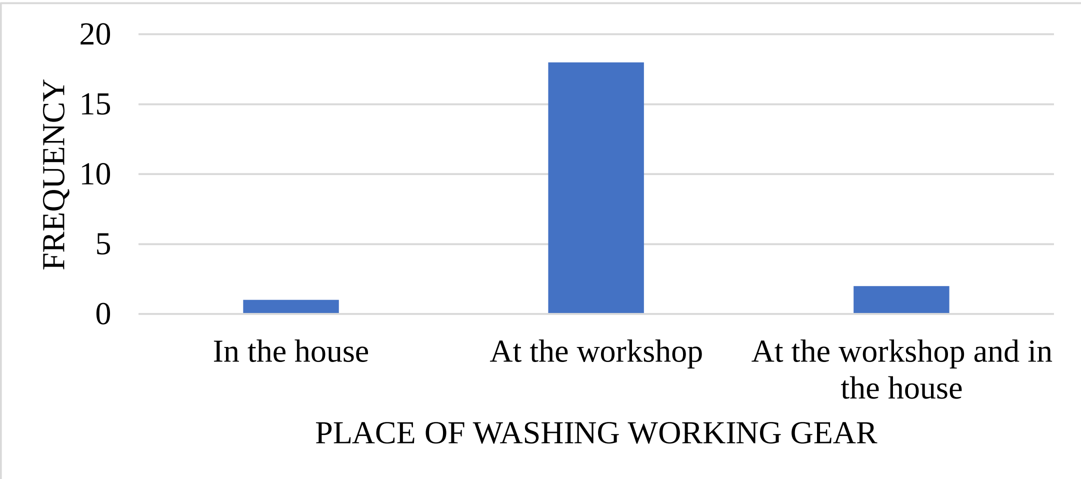

Figure 4.6: LAB recyclers' place of washing of dirty working gear

Assessment on how often working gears were washed by LAB recyclers in this study revealed that occurred from an everyday practice to thrice a week frequency. Washing of gears once a week, was the commonest safety practice in this study. Recyclers involved in this practice represented 61.9%. Recyclers that practiced everyday washing of gears represented 9.5%, whereas 4.8% reprsented those who washed gears every two days.

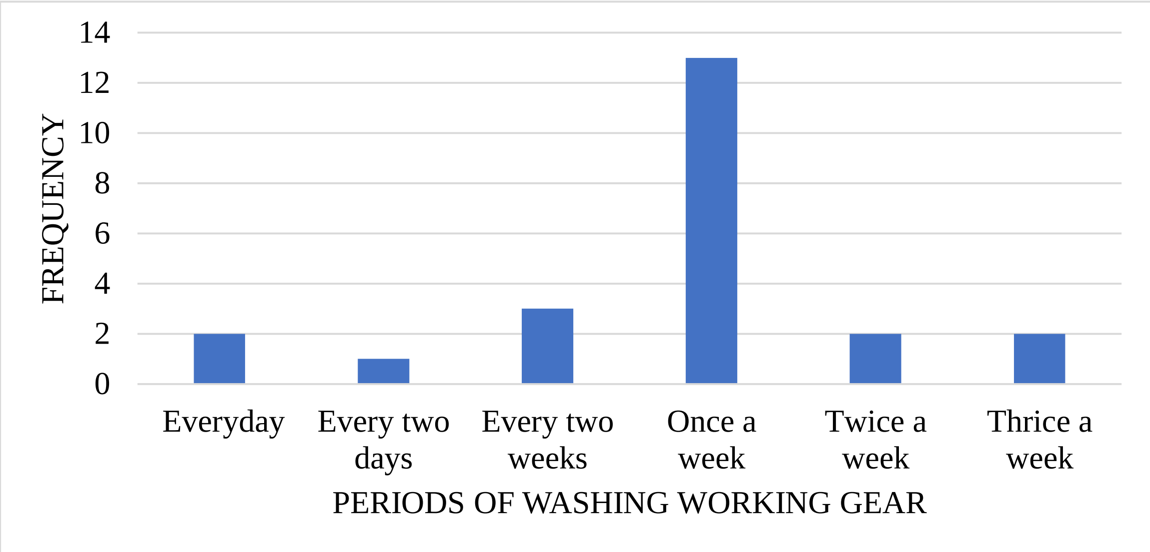

Figure 4.7: Frequency of washing of working gear by LAB recyclers

Place of eating meals by recyclers in Suame Magazine in this study, was either infront of the shop or at place of rest at the workshop. Meals were taken mostly infront of workshops.

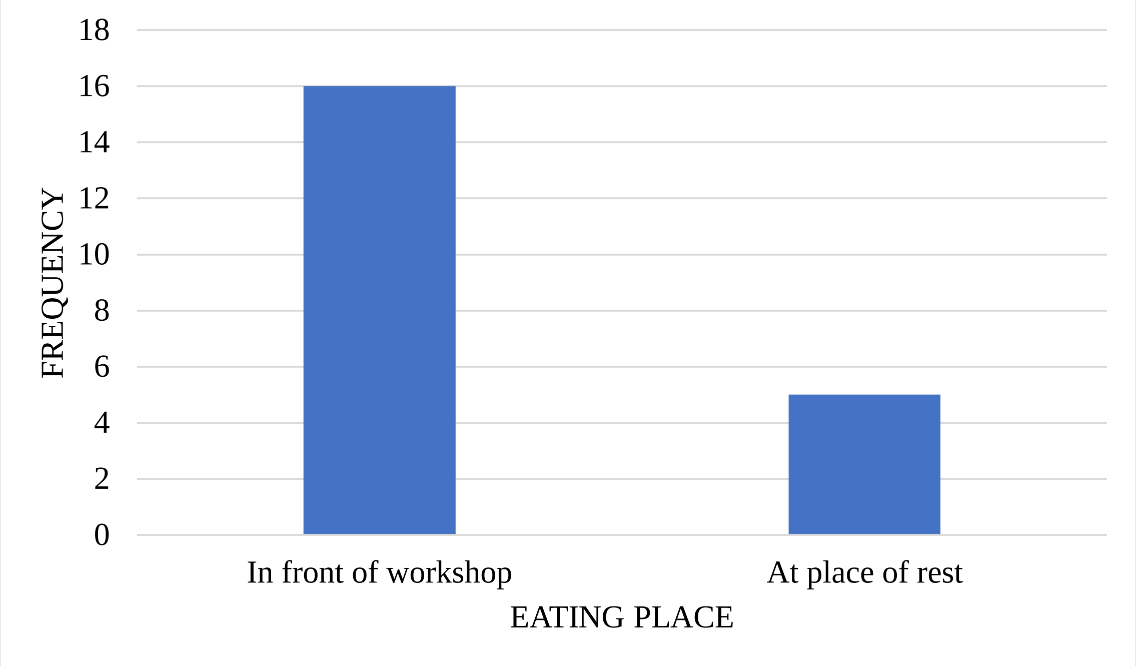

Figure 4.8: Eating place of LAB recyclers

4.3 Awareness Attitude of LAB Recyclers at Suame Magazine

Contact with LABs by recyclers at Suame Magazine was either by everyday contact or seldom contact. Recyclers that came into contact with LABs eachday represented 90.5% of respendedents, where as the remainder had seldom contacts.

In this study, some recyclers generated no waste, where as nature of waste by those who did, varied. Plastic shells was the commonest waste generated by workshops. Workshops that generated no waste after recycling represented 4.8%.

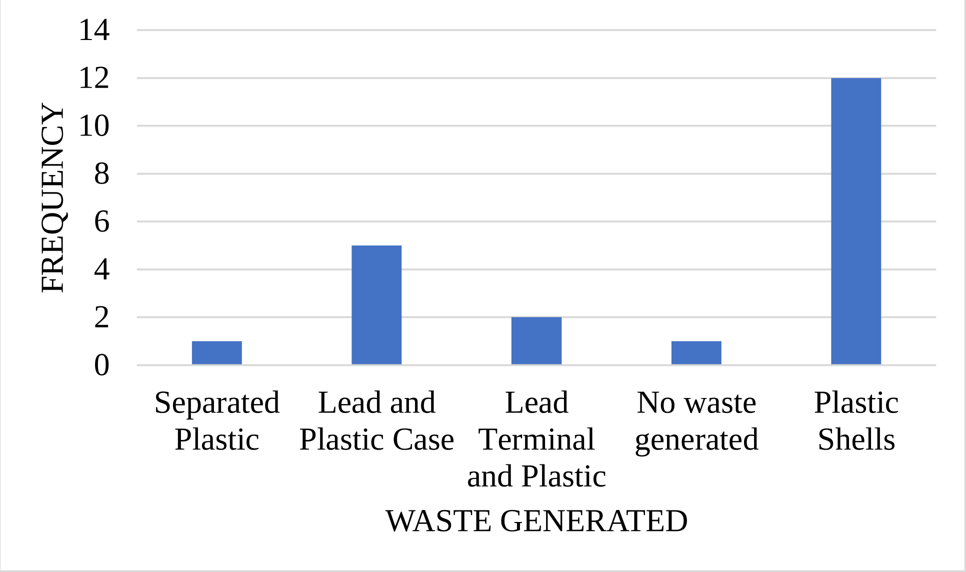

Figure 4.9: Nature of waste genereted from LAB recycling.

Waste generated after recycling is diposed off by three ways in this study; burning, recycling of waste and selling of waste. Waste generated was disposed off predominantly by selling as scraps. Workshops that recycled waste generated for lead particles represented 14.3%.

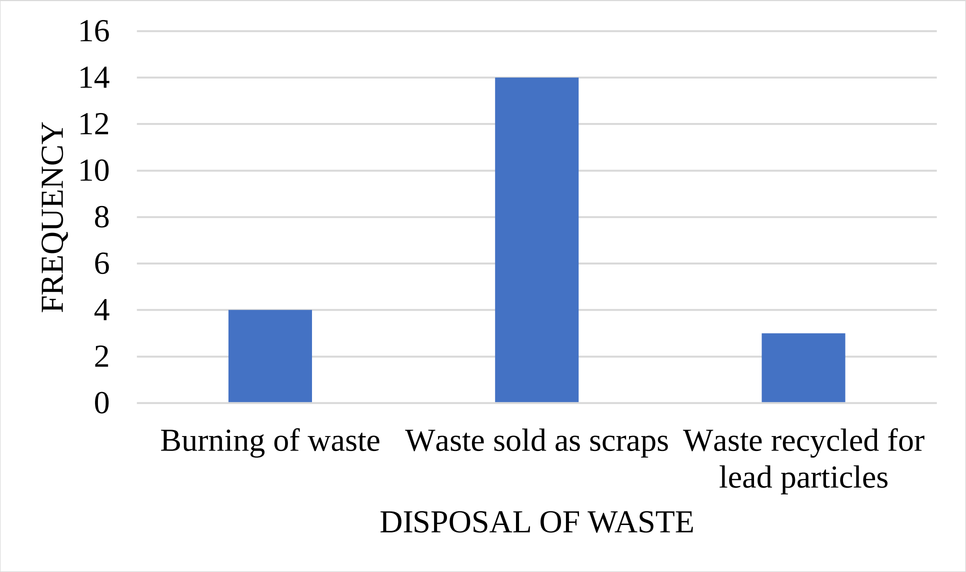

Figure 4.10: Method of disposal of waste generated from recycling.

4.4 Observational Checklist on LAB Recyclers at Suame Magazine

Assessment of the use of personal protective equipment by recyclers in this study reveals in all 21 workshops, recyclers did not use helmets and earmuffs. Recyclers in 21 workshops that protected hands with gloves represented 14.3%. Protection of the nose from gases emitted with nose masks was practised in 23.8% of the workshops assessed.

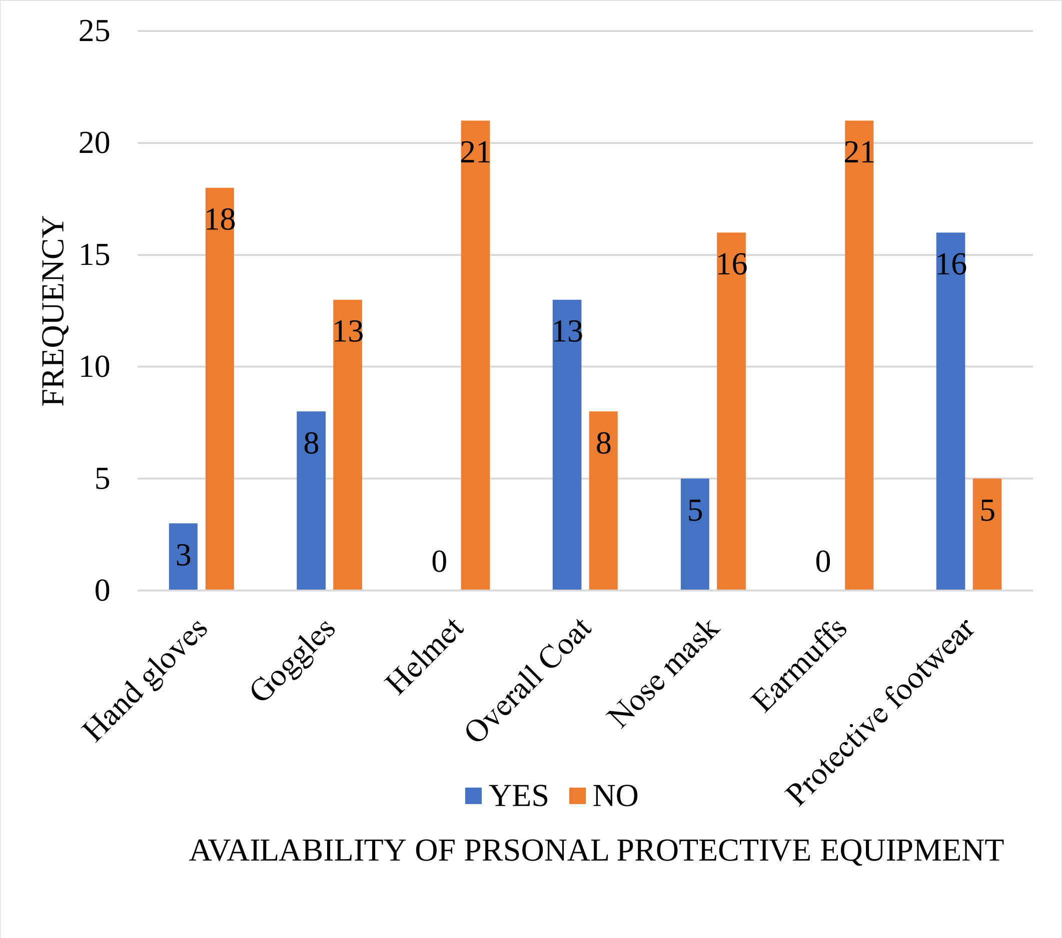

Figure 4.11: Use of Personal protective equipment during working hours

Observational checklist on ventilation sysyem in workshops, revealed the absence of both windows and extractors in all workshops.

4.5 Lead levels in Soil and Air

Levels of Pb measured in both air and soil samples from LAB recycling workshops were detectable. Distribution of Pb ranged from 0.37 to 4.18 mg/kg, 33.40 to 92.51 mg/kg and 7.25 to 84.50 mg/kg in air particulates, soil samples from outside of the workshop and soil samples from inside of the workshop respectively. Measured levels of Pb were lowest in air samples relative to soil samples. Workshops 17 recorded the lowest concentration of Pb whereas workshop 9 recorded the highest concentration in air particulate. Workshops 3 and 4 recorded the lowest and highest concentration of Pb respectively in soil samples sampled inside workshops. Distribution of Pb in soil outside workshops was highest in Workshop 9 and lowest in Workshop 7.

Table 4.1: Concentration of Pb (mg/kg) in air and soil samples from LAB recycling workshops.

	CONCENTRATION OF Pb (mg/kg)		
		SOIL SAMPLE	
WORKSHOP (WS)	AIR SAMPLE (AF)	INSIDE WORKSHOP (ASA)	OUTSIDE WORKSHOP (ASB)
WS1	0.85	57.77	57.75
WS2	3.26	21.19	68.91
WS3	0.91	7.25	75.67
WS4	2.68	84.50	40.18
WS5	1.26	56.58	80.35
WS6	1.24	8.18	48.75
WS7	1.25	40.96	33.40
WS8	3.32	27.86	56.22
WS9	4.18	44.69	92.51
WS10	2.96	23.25	46.75
WS11	2.08	82.58	74.68
WS12	2.03	29.22	75.05
WS13	2.38	83.25	42.83
WS14	3.54	47.20	69.86
WS15	0.77	70.54	41.50
WS16	3.08	26.25	45.18
WS17	0.37	69.68	61.38
WS18	1.84	74.95	76.69
WS19	1.30	44.69	49.65
WS20	1.65	36.46	39.30
WS21	2.93	60.19	61.19

4.6 Health Risk Assessment of Pb Exposure in Adults Via Dermal and Inhalation Routes of Air Particulates and Soil Samples at Lab Recycling Workshops in the Suame Magazine Industrial Area

Tables 4.2 and 4.3 show non-carcinogenic health risk assessment on adult exposure to Pb via inhalation and dermal contact respectively. In this investigation, calculated Hazard quotient values via inhalation did not exceed the acceptable level of one (1) set by the USEPA in air particles at all LAB recycling workshops and soil samples outside and within all LAB recycling workshops. Adults exposed to Pb via dermal contact had HQ values lower than one in all samples collected at LAB recycling workshops.

Table 4.2: Non-carcinogenic health risk assessment on lead exposure in adults through inhalation of soil and air.

			SOIL SAMPLE			
	AIR SAMPLE (AF)		INSIDE WORKSHOP (ASA)		OUTSIDE WORKSHOP (ASB)	
WORKSHOP (WS)	ADDinh	HQinh	ADDinh	HQinh	ADDinh	HQinh
WS1	1.71E-11	4.89E-10	1.16E-09	3.33E-08	1.16E-09	3.32E-08
WS2	6.57E-11	1.88E-09	4.27E-10	1.22E-08	1.39E-09	3.97E-08
WS3	1.83E-11	5.24E-10	1.46E-10	4.17E-09	1.52E-09	4.36E-08
WS4	5.40E-11	1.54E-09	1.70E-09	4.86E-08	8.09E-10	2.31E-08
WS5	2.54E-11	7.25E-10	1.14E-09	3.26E-08	1.62E-09	4.62E-08
WS6	2.50E-11	7.14E-10	1.65E-10	4.71E-09	9.82E-10	2.81E-08
WS7	2.52E-11	7.19E-10	8.25E-10	2.36E-08	6.73E-10	1.92E-08
WS8	6.69E-11	1.91E-09	5.61E-10	1.60E-08	1.13E-09	3.24E-08
WS9	8.42E-11	2.41E-09	9.00E-10	2.57E-08	1.86E-09	5.32E-08
WS10	5.96E-11	1.70E-09	4.68E-10	1.34E-08	9.42E-10	2.69E-08
WS11	4.19E-11	1.20E-09	1.66E-09	4.75E-08	1.50E-09	4.30E-08
WS12	4.09E-11	1.17E-09	5.89E-10	1.68E-08	1.51E-09	4.32E-08
WS13	4.79E-11	1.37E-09	1.68E-09	4.79E-08	8.63E-10	2.47E-08
WS14	7.13E-11	2.04E-09	9.51E-10	2.72E-08	1.41E-09	4.02E-08
WS15	1.55E-11	4.43E-10	1.42E-09	4.06E-08	8.36E-10	2.39E-08
WS16	6.20E-11	1.77E-09	5.29E-10	1.51E-08	9.10E-10	2.60E-08
WS17	7.45E-12	2.13E-10	1.40E-09	4.01E-08	1.24E-09	3.53E-08
WS18	3.71E-11	1.06E-09	1.51E-09	4.31E-08	1.54E-09	4.41E-08
WS19	2.62E-11	7.48E-10	9.00E-10	2.57E-08	1.00E-09	2.86E-08
WS20	3.32E-11	9.50E-10	7.35E-10	2.10E-08	7.92E-10	2.26E-08
WS21	5.90E-11	1.69E-09	1.21E-09	3.46E-08	1.23E-09	3.52E-08

Table 4.3: Non-carcinogenic health risk assessment on lead exposure in adults via dermal contact

			SOIL SAMPLE			
	AIR SAMPLE (AF)		INSIDE WORKSHOP (ASA)		OUTSIDE WORKSHOP (ASB)	
WORKSHOP (WS)	ADDderm	HQderm	ADDderm	HQderm	ADDderm	HQderm
WS1	4.85E-09	1.38E-06	3.29E-07	9.41E-05	3.29E-07	9.41E-05
WS2	1.86E-08	5.31E-06	1.21E-07	3.45E-05	3.93E-07	1.12E-04
WS3	5.19E-09	1.48E-06	4.13E-08	1.18E-05	4.31E-07	1.23E-04
WS4	1.53E-08	4.36E-06	4.82E-07	1.38E-04	2.29E-07	6.54E-05
WS5	7.18E-09	2.05E-06	3.23E-07	9.21E-05	4.58E-07	1.31E-04
WS6	7.07E-09	2.02E-06	4.67E-08	1.33E-05	2.78E-07	7.94E-05
WS7	7.13E-09	2.04E-06	2.33E-07	6.67E-05	1.90E-07	5.44E-05
WS8	1.89E-08	5.41E-06	1.59E-07	4.54E-05	3.20E-07	9.16E-05
WS9	2.38E-08	6.81E-06	2.55E-07	7.28E-05	5.27E-07	1.51E-04
WS10	1.69E-08	4.82E-06	1.33E-07	3.79E-05	2.66E-07	7.61E-05
WS11	1.19E-08	3.39E-06	4.71E-07	1.34E-04	4.26E-07	1.22E-04
WS12	1.16E-08	3.31E-06	1.67E-07	4.76E-05	4.28E-07	1.22E-04
WS13	1.36E-08	3.88E-06	4.75E-07	1.36E-04	2.44E-07	6.97E-05
WS14	2.02E-08	5.77E-06	2.69E-07	7.69E-05	3.98E-07	1.14E-04
WS15	4.39E-09	1.25E-06	4.02E-07	1.15E-04	2.37E-07	6.76E-05
WS16	1.76E-08	5.02E-06	1.50E-07	4.28E-05	2.58E-07	7.36E-05
WS17	2.11E-09	6.03E-07	3.97E-07	1.13E-04	3.50E-07	1.00E-04
WS18	1.05E-08	3.00E-06	4.27E-07	1.22E-04	4.37E-07	1.25E-04
WS19	7.41E-09	2.12E-06	2.55E-07	7.28E-05	2.83E-07	8.09E-05
WS20	9.41E-09	2.69E-06	2.08E-07	5.94E-05	2.24E-07	6.40E-05
WS21	1.67E-08	4.77E-06	3.43E-07	9.80E-05	3.49E-07	9.97E-05

Table 4.4 shows values from carcinogenic risk assessment on adult exposure to Pb via dermal contact and through inhalation. Adult cancer risk from inhaled exposure to air particulate, soil inside and soil outside LAB recycling workshops in the Suame Magazine Industrial area ranged from 3.13E-13 to 3.54E-12, 6.13E-12 to 7.14E-11, and 2.83E-11 to 7.81E-11, respectively. Again, adult cancer risk through dermal contact to air particulate, soil inside and soil outside LAB recycling workshops in the Suame

Magazine Industrial area ranged from 8.86E-11 to 1E-09, 1.74E-09 to 2.02E-08, and 8E-09 to 2.21E-08, respectively. It was observed that the carcinogenic risk is highest in workshop 15 (9.94E-09) followed by workshops 4 and 20 (9.62E-09 and 9.41E-09 respectively) through dermal contact.

Table 4.4: Carcinogenic risk assessment on lead exposure in adults via both dermal contact and inhalation

			SOIL SAMPLE			
	AIR SAMPLE (AF)		INSIDE WORKSHOP (ASA)		OUTSIDE WORKSHOP (ASB)	
WORKSHOP (WS)	CRinh	CRderm	CRinh	CRderm	CRinh	CRderm
WS1	7.18E-13	2.03E-10	4.87E-11	1.38E-08	4.87E-11	1.38E-08
WS2	2.76E-12	7.80E-10	1.79E-11	5.07E-09	5.84E-11	1.65E-08
WS3	7.69E-13	2.18E-10	6.13E-12	1.74E-09	6.38E-11	1.81E-08
WS4	2.27E-12	6.42E-10	7.14E-11	2.02E-08	3.40E-11	9.62E-09
WS5	1.07E-12	3.02E-10	4.79E-11	1.35E-08	6.80E-11	1.92E-08
WS6	1.05E-12	2.97E-10	6.93E-12	1.96E-09	4.12E-11	1.17E-08
WS7	1.06E-12	2.99E-10	3.47E-11	9.81E-09	2.83E-11	8.00E-09
WS8	2.81E-12	7.95E-10	2.36E-11	6.67E-09	4.75E-11	1.35E-08
WS9	3.54E-12	1.00E-09	3.78E-11	1.07E-08	7.81E-11	2.21E-08
WS10	2.50E-12	7.09E-10	1.97E-11	5.57E-09	3.96E-11	1.12E-08
WS11	1.76E-12	4.98E-10	6.97E-11	1.98E-08	6.30E-11	1.79E-08
WS12	1.72E-12	4.86E-10	2.47E-11	7.00E-09	6.34E-11	1.80E-08
WS13	2.01E-12	5.70E-10	7.06E-11	1.99E-08	3.62E-11	1.03E-08
WS14	2.99E-12	8.47E-10	3.99E-11	1.13E-08	5.92E-11	1.67E-08
WS15	6.51E-13	1.84E-10	5.96E-11	1.69E-08	3.51E-11	9.94E-09
WS16	2.60E-12	7.37E-10	2.22E-11	6.28E-09	3.82E-11	1.08E-08
WS17	3.13E-13	8.86E-11	5.88E-11	1.67E-08	5.21E-11	1.47E-08
WS18	1.56E-12	4.40E-10	6.34E-11	1.79E-08	6.47E-11	1.84E-08
WS19	1.10E-12	3.11E-10	3.78E-11	1.07E-08	4.20E-11	1.19E-08
WS20	1.39E-12	3.95E-10	3.09E-11	8.73E-09	3.33E-11	9.41E-09
WS21	2.48E-12	7.01E-10	5.08E-11	1.44E-08	5.17E-11	1.46E-08

CHAPTER FIVE

DISCUSSION

5.1 Awareness and Practice of Occupational Health And Safety Measures By Lab Recyclers

In Ghana, LAB recycling is one of the many artisanships that are informal hence unregulated hence OHS practices not largely adhered to Ahiale *et al*. (2019). The age range of recyclers in this study was 22-52 years, with an average age of 37.5±22. A study by Ahiale *et al*. (2019) also revealed an average age of 37.23 for LAB recyclers in Kumasi. Another study by Dartey *et al*. (2017), reported an age range of 20-49 years with an average of 31.8 years. In this study, the average work experience of Lab recyclers is 15.8 years, whereas it is 12.73 years in Ahiale *et al*., (2019) study. Work experience according to Dartey *et al*. (2017) of LAB recyclers at Suame Magazine ranged between 1-30 years, with an average work experience of 11.4 years.

The practice of washing off stained hands with water and soap or a washing detergent during LAB recycling was carried out by 81% of respondents. However, the use of gloves as a PPE during recycling was practised by just 14.3%. From such practices, education intervention of the benefit on the use of gloves among LAB recyclers had not been far reached.

It is ideal working gear is washed eachday based on the potential health effect recycling of LAB poses to recyclers. Assessment on frequency of washing of working gear shows a poor hygiene practice by recyclers. Recyclers that washed working gear everyday represented 9.5%. Washing of working gear once a week was the predominant practice in this study. The extent of poor industrial hygiene in terms of cleanliness of working gear went as far as recyclers washing their gear every two weeks (14.3%).

The absence of a ventilation system in all workshops assessed coupled with the use of protective covering for the nose during workhouse by only 23.8% of recyclers raises health concerns. Exposure to toxic gases released during work hours becomes inevitable. From observation, there were no extractors indicating the lack of knowledge on its importance considering the hazards of this artisanship. Release of toxic gases during work hours will be trapped in air particulates at workshops.

Assessment of place of taking meals revealed none of the recyclers took meals inside workshops. Meals were mostly taken infront of workshops while 23.8% took meals at place of rest. Concerns on health issues could be raised firstly based on recyclers washing stained hands with just water (19.0%) and secondly from observation, all recyclers in this study avoided the use of gloves while handling LABs.

The practice of burning wastes generated from LAB recycling contributes to air pollution. The composition of LAB consist of heavy metals such as Pb, and Sb as well as compounds of S and Pb. Release of such toxicants into the atmosphere through such disposal methods raises issues of health concern. Recyclers that recycled spent LAB for lead particles could face Pb toxicity if they are ignorant of OHS practices.

5.2 Concentration of Pb in Air Borne Particulate Matter and Soil in and Around LAB Recycling Workshops

Concentrations of Pb at LAB recycling workshops were detectable in soil and air samples shown by Table 4.1. A two-factor analysis of variance without replication revealed, at an alpha value of 0.05, there was no significant variation in measured Pb levels when the 21 workshops were compared, and this occurred at a p-value of 0.52. A significant variation however existed when measured level of Pb were compared amongst air particulates, soil outside and soil inside LAB recycling workshops. This occurred at a p-value of 2.5E-13.

Distribution of Pb were lowest in air particulates than in soil samples at LAB recycling workshops. Levels of Pb in air particulates ranged from 0.37–4.18 mg/kg, thereby averaging 2.09±1.07 mg/kg. A national ambient air quality standard (NAAQS) of 0.5 μg/m^3 (0.001mg/kg) for Pb in air particulate has been set by USEPA (Munir et al., 2003). Measured levels of Pb in air particulates far exceeded this quality standard. This raise concerns on airborne toxicity of Pb to LAB recycling workshops at Suame Magazine, as well as other workshops with similar conditions all over the country. These levels of Pb that do not meet NAAQS may be attributed to poor ventilation in LAB workshops, which was observed in this study. Emission of Pb from acts of reconditioning of LABs in order to produce functioning second hand batteries to the local market could be attributed to elevated levels of Pb in air particulates. Assessment on ventilation systems in workshops revealed the absence of windows and extractors.

Distribution of Pb in soil particles inside LAB recycling workshops ranged from 7.25–84.5 mg/kg, with a mean value of 47.49±24.29 mg/kg, whereas levels ranged from

33.40-92.51 mg/kg averaging 58.94±16.44 mg/kg outside workshops. European Soil Bureau (ESB) establishes a value of 100mg/kg as the maximum allowable limit of Pb in soil. According to USEPA, the maximum Pb soil concentration is 800mg/kg for industrial lands and 400 mg/kg for residential lands. Measured levels of Pb both inside and outside workshops did not exceed established values set by both ESB and USEPA. A similar study by Acheampong *et* al. (2016) in the Suame Industrial Area observed 175-730 mg/kg of measured levels of Pb in soils sampled at a 0–10 cm depth. Measured levels far exceed Pb levels in this study. The inconsistency in measured levels may be attributed to depth at which samples were taken, scale of LAB recycling at workshops as well as techniques employed in detecting and quantifying distributed heavy metals. According to Kitila (2018), the practice of uncontrolled draining of electrolytes in LAB inorder to earn more money for recycling could be attributed to the distribution of Pb in the soil inside and outside of workshops. This is due to the dissolution of lead and lead particles in the electrolyte (solution of water and sulphuric acid) to be ttttt out. From Table 4.1, distribution of Pb in soils is evident acid drainage occurs in most LAB recycling workshops from. Furthermore, temporal keeping of empty cases of LAB outside workshops before permanent disposal could be attibuted. Leaching of incompletely drained electrolyte from empty cases of LAB after battery breaking and lead scrap extraction into soil during temporal storage outside workshops could be the main cause. Workshops that dispose collected electrolytes during acid drainage outside their workshops could be the reason behind significant Pb levels in soils outside workshops.

5.3 Health Risk Assessment for Adults on Exposure to Air And Soil from Lab Recycling Workshops

In this study, the age range of LAB recycling workers was 22-52, and again adult workers being the predominant taskforce in the Suame Magazine industrial area, hence a health risk assessment conducted for only adults deemed it fit. Risk assessment by the USEPA RAGs format employed in this study constitutes two risk forms. A carcinogenic risk assessment and a non-carcinogenic risk assessment. Adult exposure to Pb is mainly through inhalation and skin contact.

Non-carcinogenic health risk to a population on exposure to a heavy metal or multiple metals, is determined by vlaues of Hazard quotient or Hazard index respectively via the route for exposure. Hazard quotient (HQ) is the potential for non-carcinogenic health risk to a population or vulnerable groups on exposure to a single potentially toxic element (PTE) (USEPA, 2011). Tables 4.2 presents calculated values for HQ via inhalation whereas Table 4.3 presents HQ values via dermal contact. According to USEPA (2011), a potential for non-cancer risk exists when $HQ \geq 1$. From tables 4.2 and 4.3, via inhalation and through dermal contact, adult exposure to Pb from air particulates and soil from all workshops possess no significant non-carcinogenic health risk ($HQ<1$).

Carcinogenic health risk is determined by calculated values for cancer risk. When exposure is to two or more potentially toxic elements, cancer risk by the individual metals are summed to obtain a total cancer risk value. Cancer risk and Total cancer risk values in the range of 10^{-6} to 10^{-4}, established by USEPA (2011) confer no significant risk for cancer. Values greater than or equal to 10^{-4} is an indication for potential cancer risk. However, values lesser than 10^{-6}, do no confer significant cancer risk. From Table 7, calculated values were all lesser than the safe lower limit (10^{-6}) on exposure by inhalation and skin contact. This implies a potential for sigificant cancer risk does not exist to LAB recyclers in the Suame Magazine industrial area.

Regardless of an absence of potential cancer and non-cancer health risk from Pb exposure to LAB recyclers in the Suame Magazine industrial area, precautionary measures and policies should still be put in place as well as enforcing already existing ones. Assessment of artisanal LAB recyclers' awareness of required OHS measures as well as OHS practices revealed significant contact time (15 to 90 minutes) with LAB (Figure 4.4) and poor personal hygienie of working gears (only 9.5% washed working gear each day and 61.9% washed gear once in a week) (Figure 4.7). Again, 90.5% had contact with LAB eachday in their total workdays. Regardless of an absence of potential carcinogenic and non-carcinogenic health risks, bio-accumulation of Pb in the bodies of artisanal LAB recycler's with time could result in chronic or acute health conditions. Even at very low concentrations, toxicity of lead has been associated with damages to several organ systems; urinary, hemopoetic, cardiovascular, gastrointestinal, nervous and reproductive systems (ATSDR, 2007; Haider *et al*.,2013)

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary of the Work

The objective of this study was to evaluate the occupational health and safety practices of artisans involved in lead-acid battery recycling in Suame Magazine, Kumasi. The study used questionnaires to assess artisans' knowledge and practices, including handwashing and wearing protective gear. There were about thirty-five workshops in the magazine area but twenty-one (21) LAB workshops were selected using the snowball sampling technique.

The study found that exposure to lead toxicity primarily occurs through the skin and inhalation. Risk assessments were conducted following guidelines from the United States Environmental Protection Agency. The age range of participants was 22 to 52 years, and over half had a pre-tertiary education. Contact duration with lead-acid batteries ranged from 15 to 90 minutes per day. Soap and water were the most common method for hand stain removal. The common safety practice was washing gear once a week. Plastic shells were the main waste generated, and most waste was sold as scraps.

Lead levels were detectable in air and soil samples from the workshops. Adult cancer risk from inhalation exposure ranged from 3.13E-13 to 3.54E-12. Observations showed a lack of extractors and the release of toxic gases during work. Meals were often consumed in front of workshops. Statistical analysis found no significant variation in lead levels among the workshops but a significant variation between air and soil samples. The levels of lead in air particulates and soil samples exceeded national ambient air quality standards. Non-carcinogenic health risk depends on the Hazard quotient or Hazard index, while carcinogenic risk is determined by cancer risk values.

Overall, this study highlights the need for improved occupational health and safety practices in lead-acid battery recycling.

6.2 Conclusion

Respondents exhibited lower to moderate awareness of the required occupational health and safety measures as the results showed that almost all the workers washed their hands with only water after working on the LAB.

Lead acid battery recycling workers all used safety boots but generally had inadequate personal protective equipment such as helmets, dust masks and goggles whilst on site. The level of awareness of the workers on lead and its possible side effects in the LAB recycling industries was so low that they did not take any protective measures to avoid exposure.

Levels of Pb measured in both air and soil samples from LAB recycling workshops were detectable. Distribution of Pb ranged from 0.37 to 4.18 mg/kg, 33.40 to 92.51 mg/kg and 7.25 to 84.50 mg/kg in air particulates, soil samples from outside the workshop and soil samples from inside the workshop respectively.

Estimation of non-carcinogenic and carcinogenic risk of the adult population through inhalation and dermal absorption all revealed that the artisans may not be at risk of health complications with the current daily levels of lead exposure, however, long-term exposure could result in adverse health complications to the exposed population. The concentrations of lead in the soils and air all exceeded the recommended daily limits of 0.3 mg/kg and 0.5 mg/kg**.**

6.3 Recommendation

The following recommendations were made from the study:

The Environmental Protection Agency (EPA) should educate artisans on health hazards posed by contaminants through rigorous sensitization. The government of Ghana should implement strict regulations and policies for the daily use of appropriate PPEs. Ghana's government is urged to enforce national regulations on workplace safety and health. It is crucial to provide proper ventilation systems like windows and extractors to minimize lead exposure.

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APPENDICES

Appendix I

Questionnaire

I am Charles Leo Obeng, a student of AAMUSTED conducting research on *Occupational Health and Safety Practices among Artisans Involved in Lead-Acid Battery recycling at Suame Magazine in the Kumasi Metropolis*. The study is solely for academic purposes, and will therefore, not be used for any other purpose. Be assured that the confidentiality of the information you provide will be respected.

Instruction: Please tick **(√)** inside the box **[ ]** provided to indicate your choice of response for any of the questions below (where applicable). You may also be requested to provide your own responses to some of the questions.

Date of Administration of questionnaire: ______/______/___________

DD MM YY

Questionnaire number: …………… Site name: ………………………………

SECTION A: BACKGROUND INFORMATION Please kindly indicate the best description of you with respect to the following questions.			
No.	Variable	Category	Tick **(√)** here
1	Gender?	Male	[1]
		Female	[2]
2	What is your highest level of education?	No formal education	[1]
		Pre-tertiary level	[2]

		Tertiary level	[3]
		Response	
3	What is your age?	…………years.	
4	How many years have you been doing this work?	…………years.	
SECTION B: SAFETY PRACTICES Inquire from the workers about their safety practices in respect of the following areas.			
5	What do you do with your stain hands when working with Lead acid battery?	………………………………………… …………………………………….	
6	What do you use to clean the stain hands?		
7	How often do you wash your working gear?		
8	Where do you wash your working gear?		

9	Where do you eat during working hours?	
10	How many hours do you spent when working on Lead acid battery?	
11	Do you know any risk associated with the Lead?	
SECTION D: AWARENESS ATTITUDES		
12	What waste do you generate here?	
13	What do you do with the waste part?	
14	What have you learnt about Lead contamination from Lead acid battery?	
15	How does the exposure of Lead affect the environment?	
16	How does the exposure of Lead affect the human?	
17	How often do you come into contact with Lead acid battery?	

SECTION E: OBSERVATIONAL CHECKLIST			
Personal Protective Equipment			Tick (√)
18	What protective equipment do you wear during working hours?	Helmet	[ ]
		Hand gloves	[ ]
		Goggles	[ ]
		Protective footwear	[ ]
		Overall coat	[ ]
		Nose mask	[ ]
		Earmuffs	[ ]

Ventilation				
General environment		Enclosed space	Open space	Observation
19	windows			
20	Number of windows			
21	Number of windows blocked			
22	Number of Windows Opened			
23	Availability of extractor			

24.What is the purpose of extractor?

…………………………………………………………………………………………

…………………………………………………………………………………………

…………………………………………………………………………………………

……………………………………………...

Appendix II

Lead concentration in the air particulate inside the workshops

LAB #	LABELS	Pb ppm	Pb ppm/filter
1	**AF 1**	0.00017	0.85
2	**AF 2**	0.00104	3.26
3	**AF 3**	0.00018	0.91
4	**AF 4**	0.00064	2.68
5	**AF 5**	0.00040	1.26
6	**AF 6**	0.00055	1.24
7	**AF 7**	0.00050	1.25
8	**AF 8**	0.00040	3.32
9	**AF 9**	0.00100	4.18
10	**AF 10**	0.00083	2.96
11	**AF 11**	0.00116	2.08
12	**AF 12**	0.00041	2.03
13	**AF 13**	0.00038	2.38
14	**AF 14**	0.00113	3.54
15	**AF 15**	0.00015	0.77
16	**AF 16**	0.00062	3.08
17	**AF 17**	0.00004	0.37
18	**AF 18**	0.00066	1.84
19	**AF 19**	0.00031	1.30
20	**AF 20**	0.00033	1.65

21	**AF 21**	0.00152	2.93

Appendix III

Lead concentration outside the workshop

LAB #	LABELS	Pb ppm	Pb ppm/soil
1	**ASB 1**	**1.16**	57.75
2	**ASB 2**	**1.39**	68.91
3	**ASB 3**	**1.52**	75.67
4	**ASB 4**	**0.81**	40.18
5	**ASB 5**	**1.62**	80.35
6	**ASB 6**	**0.98**	48.75
7	**ASB 7**	**0.67**	33.40
8	**ASB 8**	**1.13**	56.22
9	**ASB 9**	**1.87**	92.51
10	**ASB 10**	**0.94**	46.75
11	**ASB 11**	**1.50**	74.68
12	**ASB 12**	**1.51**	75.05
13	**ASB 13**	**0.86**	42.83
14	**ASB 14**	**1.40**	69.86
15	**ASB 15**	**0.83**	41.50
16	**ASB 16**	**0.91**	45.18
17	**ASB 17**	**1.23**	61.38
18	**ASB 18**	**1.54**	76.69
19	**ASB 19**	**1.00**	49.65
20	**ASB 20**	**0.79**	39.30
21	**ASB 21**	**1.23**	61.19

Appendix IV

Lead concentration inside the workshops

LAB #	LABELS	Pb ppm	Pb ppm/soil
1	**ASA 1**	1.16	57.77
2	**ASA 2**	0.43	21.19
3	**ASA 3**	0.15	7.25
4	**ASA 4**	1.70	84.50
5	**ASA 5**	1.14	56.58
6	**ASA 6**	0.17	8.18
7	**ASA 7**	0.83	40.96
8	**ASA 8**	0.56	27.86
9	**ASA 9**	0.90	44.69
10	**ASA 10**	0.47	23.25
11	**ASA 11**	1.66	82.58
12	**ASA 12**	0.59	29.22
13	**ASA 13**	1.67	83.25
14	**ASA 14**	0.95	47.20
15	**ASA 15**	1.42	70.54
16	**ASA 16**	0.53	26.25
17	**ASA 17**	1.40	69.68
18	**ASA 18**	1.51	74.95
19	**ASA 19**	0.90	44.69
20	**ASA 20**	0.73	36.46

21	**ASA 21**	1.21	60.19

Appendix V

Details of sampling sites, time and geographical positioning system (GIS) coordinates

soil sample	Air sample	Air sample Time start	Air sample Time end	Minutes	GPS coordinates	
					Latitudes	Longitude
1. ASA/ASB	AF-01	9:03 am	4:35pm	208 min	N6˚43'49.794	W1˚37'55.308
2.ASA/ASB	AF-02	9:23 am	4:41pm	431 min	N6˚43'50.712	W1˚37'54.462
3.ASA/ASB	AF-03	9:38 am	4:46pm	433min	N643''52.908	W137'55.944
4.ASA/ASB	AF-04	10:12am	4:19pm	384min	N643'55.812	W138'6.24
5.ASA/ASB	AF-05	10:18am	4:01pm	343min	N644'12.804	W138'16.32
6.ASA/ASB	AF-06	10:55am	4:59pm	367min	N643'53.634	W137'38.376
7.ASA/ASB	AF-07	11:01am	5:02pm	365min	N643'53.635	W137'38.377
8.ASA/ASB	AF-08	8:52am	5:12pm	502min	N643'44.57	W137'52.386
9.ASA/ASB	AF-09	9:07am	5:05pm	479min	N643'38.382	W137'50.1
10.ASA/ASB	AF-10	9:28am	4:54pm	453min	N6˚43'36.6	W1˚37'40.878

Appendix V continued

1		10:01am	4:45pm	404min	N6˚43'40.788	W1˚37'36.078
12.ASA/ASB	AF-12	10:40am	4:02pm	329min	N643'50.1	W137'37.566
13.ASA/ASB	AF-13	10:46am	3:54pm	308min	N643'48-51	W137'39.996
14.ASA/ASB	AF-14	11:11am	4:30pm	302min	N643'48.3	W137'44.544
15.ASA/ASB	AF-15	9:05am	4:56pm	474min	N643'32.268	W137'26.40
16.ASA/ASB	AF-16	9:15am	4:52pm	456min	N643'33.924	W137'25.77
17.ASA/ASB	AF-17	9:50am	4:40pm	412min	N643'33.702	W137'36.876
18.ASA/ASB	AF-18	10:28am	4:25pm	365min	N643'30.864	W137'41.556
19.ASA/ASB	AF-19	10:45am	4:20pm	336min	N643'28.698	W137'40.422
20.ASA/ASB	AF-20	10:55am	4:15pm	325min	N643'28.182	W137'38.964
21.ASA/ASB	AF-21	11:10am	5:05pm	320min	N634'29.214	W137'33.204