AIRBORNE LEAD EXPOSURE AMONG INFORMAL SECTOR WORKERS AT KAMUKUNJI "JUA KALI" SHEDS IN NAIROBI COUNTY, KENYA

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Airborne Lead Exposure among Informal Sector Workers at Kamukunji “Jua Kali” Sheds in Nairobi County, Kenya

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

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This thesis has been submitted for examination with our approval as university supervisors.

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DEDICATION

I dedicate this work to God, my husband Robert Kitui, children Joshua and Jeshua Kitui, my siblings and my late parents for their love and continued support during the study.

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ACRONYMS AND ABBREVIATIONS

AAS	Atomic Absorption Spectroscopy
ACGIH	American Conference of Governmental Industrial Hygienists
ATSDR	Agency for Toxic Substances and Disease Registry
BDL	Below Detection Limit/Level
BLL	Blood Lead Levels
BP	Blood Pressure
BPb	Blood Lead
CDC	Centers for Disease Control and Prevention
DOSHS	Directorate of Occupational Safety and Health Services
EMCA	Environmental Management and Coordination Act
EPA	Environmental Protection Agency
GFAAS	Graphite Furnace Atomic Absorption Spectrophotometry
GOK	Government of Kenya
GSR	Gunshot Residue
IARC	International Agency for Research on Cancer

ICP/AES	Inductively Coupled Plasma Atomic Emission Spectroscopy
LIA	Lead in Air
LN	Legal Notice
mL	Milliliters
nm	Nano metre
NIOSH	National Institute for Occupational Safety and Health
NTP	National Toxicology Program
OSHA	Occupational Safety and Health Act
Pb	Lead
PEL	Permissible Exposure Limit
PPE	Personal Protective Equipment
TLV/TWA	Threshold Limit Value/Time Weighted Average
US EPA	United States Environmental Protection Agency
WHO	World Health Organization

ABSTRACT

Lead (Pb) is widely used in various industries during production processes which result in exposure among workers if proper occupational safety and health measures are not put in place. Lead is highly harmful to human health and the environment. In developed countries, strict controls and improvements in industrial methods have helped to ensure that occupational Lead poisoning is less prevalent whereas in developing countries, it remains a problem of huge dimensions especially in the informal sector. Previous research work has shown informal sector workers have elevated blood Lead levels which may be attributed to airborne exposure. This study sought to evaluate airborne Lead exposure among informal sector workers in Kamukunji, Nairobi County. Descriptive and experimental techniques were used in the study which the concentration of airborne Pb was determined from 34 sheds in Kamukunji and two control groups. Airborne Lead was collected on filters using air sampling pumps in 34 sheds where metal cutting, folding, heating, welding, soldering, grinding and painting works were being done. Two control areas with no known exposure to Lead were also sampled. In addition, questionnaires were issued to the selected shed leaders. The concentration of airborne Lead was determined using flame atomic absorption spectroscopy (FAAS). The study revealed that, 55.9% of the sampled sites had airborne Pb concentration (µg/m^3) ranging from 1.45 ± 0.06 µg/m^3 to 126.85 ± 20.14 µg/m^3. The control and fifteen sheds representing 44.1% had airborne Pb concentration below the detectable limits (BDL). The results obtained show that all the sampling sites had airborne Pb levels within the Kenya occupational limit of 150µg/m^3. However, four sheds (11.76%) had much high Lead in air LIA levels than the Permissible Exposure Limit (PEL) of 50 µg/m^3 set by the US OSHA standards for general industry on a Time Weighted Average (TWA) of 8 hours. The mean airborne Pb concentrations (µg/m^3) were 53.61 ± 0.60, 126.85 ± 20.14, 56.42 ± 3.05 and 117.36 ± 5.19 that were observed in sheds 6, 11, 16 and 27, respectively. From empirical perspective, 50.0% of the respondents (n= 34) had secondary education while 29.4% had primary education. The study revealed that 61.8%) of the respondents were unaware of Pb exposure and related adverse effects. Seventy-one percent (71.0%) of the respondents did not undergo medical checkups. Eighty-five (85.0%) of those who visited the hospital had cough, chest problems and blood pressure. All respondents lacked adequate protective means against exposure to Pb at their workplace. Observations made were that food production was done within the sites, which could contribute to ingestion as another route of Lead intake. It can thus be concluded that most respondents in this study were exposed to Pb levels associated with working activities hence the need for safe work practice, training programs, awareness programs among other occupational safety and health strategies to protect them from these exposures.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

The growth of the informal sector was a result of unemployment. Keith Hart was the first to introduce the term Informal Sector (King, 1996). He introduced it while making a presentation on "Informal income opportunities and urban employment in Ghana" in the Institute of Development Studies (IDS) in September 1971 at a conference co-organized by Rita Cruise O‟Brien and Richard Jolly on urban employment in Africa months before the International Labour Organisation (ILO) employment mission to Kenya came with its report "Employment Incomes and Equality" (Jolly, 2006). The informal sector comprises of micro- enterprises that has one to three workers and small-scale that consists of four to ten workers located close to each other with limited resources. Skilled, semi-skilled and unskilled workers had to come up with innovative ways to sustain themselves and earn a livelihood for themselves and their families (Njeri, 2008). In Africa, the growth rate of the informal sector has surpassed that of the formal sector (Obare, 2013). In Kenya, the latter is viewed as an important sector for employment creation, poverty alleviation and economic growth. This has been supported and compelled by the increasing awareness within the government that large projects in the industrial sector are less likely to generate the requisite employment opportunities, given the high capital intensity (Kinyua, 2014).

The Kamukunji informal sector in Nairobi County has several workgroups. The segment has the business support services who are mainly the scrap metal dealers, welding rod suppliers, gas or electrical welders, metal cutters, metal folders, paint and polish traders. The metal engineering division is focused largely with folding and pressing machines and other metal handling accessories. Metal dealers are classified and known based on the types of the products they make. Different types of metallic products are manufactured in this sector which includes kerosene lamps, wheelbarrows, sewing machine stands, chaff cutters, boxes and Aluminum cooking pans. This sector also produces diverse agricultural equipment, energy-saving stoves among many other products (Zeng, 2008). In addition, the segment is engaged in different occupational activities involving metallurgy that are highly polluting and could easily predispose workers and their families to health risks associated with Lead poisoning (Kordas *et al*., 2018).

Even though the informal sector plays a major role in the development of Kenya's economy it faces quite several challenges such as lack of occupational safety and health measures. Most of the workers in this division do not have the necessary awareness, technical support, and resources to implement occupational health and safety measures. The sector experiences poor working environment especially inadequate safety and health facilities and unsatisfactory welfare services. The production of a variety of metallic products in a poorly controlled environment is an important source of Lead exposure (Kordas *et al*., 2018). This situation presents adverse human health effects, it is detrimental to the quality of life of informal sector workers including their families (Charles, 2012). Lead exposure has been associated with devastating health effects (WHO, 2010)

There is, therefore need to determine the exposure levels of Lead (Pb) in air in the informal sector in Kamukunji with an aim of coming up with intervention measures to reduce negative health effects associated with long-term Pb exposure. This will, in turn, increase awareness to ensure the safety of the workers in this segment.

1.2 Statement of the Problem

Lead in air pollution has been linked to negative health impacts including cardiovascular diseases, stroke, lung cancer, as well as chronic obstructive pulmonary disease (Maina *et al*., 2018). High levels of Lead exposure results to damage of almost all organs of the human body, mainly the central nervous system and kidneys (Were *et al*., 2017). The lack of adequate research on occupational safety and health of Lead exposure in the informal sector presents a problem for practitioners in addressing the Pb poisoning and related health effects among the informal sector workers not just in Kenya but also in many developing countries (Kordas *et al.,* 2018). Several previous studies have been carried out to determine Pb levels in formal industries but few in the informal sector. This study was intended to fill the gap in knowledge as it focused in determining airborne Pb exposure, identifying safety practices, workplace conditions, and use of personal protective equipment (PPEs) among workers in the informal sector in Kamukunji “Jua Kali” Sheds in Nairobi County.

1.3 Justification

The growing polluting industrial activities in the informal sector that involve metallurgy in processing diverse products coupled with lack of resources and low occupational safety and health is linked to Lead poisoning (Kordas *et al*., 2018). Lead (Pb) exposure is a devastating health hazard to human beings; it causes great health concern and challenge to researchers, employers, and employees since Lead bio- accumulates in biological system, persistent in the environment and the symptoms of Lead poisoning mimics other diseases. Furthermore, most of the workers and stakeholders have limited knowledge about Lead poisoning. The findings of this research will assist in coming up with suitable intervention measures to reduce exposure to airborne Pb among informal sector workers. This will subsequently reduce the adverse health effects related to Lead exposure among workers. Most of the research on exposure levels to Pb in the informal sector has been done using blood samples (Ashraph *et al*., 2012, Njoroge *et al.*, 2008). This research work sought to undertake a broader outlook into assessing the occupational exposure to airborne Pb in the sector and recommend suitable measures to improve working conditions to reduce Pb exposure levels. Findings and recommendations arising from this study are envisioned to serve as guide to other informal sectors in Kenya.

1.4 Objectives

1.4.1 Main Objectives

To assess the levels of airborne Lead (Pb) exposure among workers in the informal sector in Kamukunji “Jua Kali” sheds within Nairobi County in Kenya.

1.4.2 Specific Objectives

1. To determine the level of airborne Pb pollution in Kamukunji “Jua Kali” sheds in Nairobi County.
2. To establish level of conformity of the work premises to the set standards of acceptable workplace airborne Pb levels.
3. To evaluate the occupational safety and health control measures in place and recommend a Lead management system to be adopted in the sector.

1.5 Research Questions

The following were research questions for the study:

1. What is the Lead in air levels that workers in Kamukunji “Jua Kali” shed are exposed to?
2. How are the Pb levels in the air of the work environment compared to the permissive exposure limit of airborne Pb levels in workers’ environment?
3. What are the available occupational safety and health measures in place to protect these workers?

1.6 Scope of the Study

The study focused on informal sector workers at Kamukunji “Jua Kali” Sheds in Nairobi County and two controls at Ongata Rongai in Kajiado county. Area airborne Lead (Pb) levels within the sheds were determined. This was done by collecting area samples at the breathing zone of the workers using air sampling pumps from the thirty-four sheds in the production areas of the Kamukunji “Jua Kali” sheds that were classified by Nelima, (2015) and a control area with no known source of Lead exposure. The collected samples were thereafter analyzed using Atomic Absorption Spectrophotometry. The airborne Lead results were compared with established workplace Lead in air standards in Kenya and international standards to check for conformance. Related information on working conditions, safety and health measures was obtained using observations, interviews and questionnaires.

1.7 Study Limitations

The study was also limited to only determining Pb in air and not in biological samples such as urine or blood. The study was also limited to the responses from the selected shed leaders and not all the workers in the area.

1.8 The Theoretical Review/ Conceptual Framework

According to Kumar (2005), conceptual modeling establishes the representation of entities and their relationships in a format that is easy to read and understand. The conceptual framework in Figure 1.1 shows the diagrammatic relationship between independent and dependent variable that are applicable to this study.

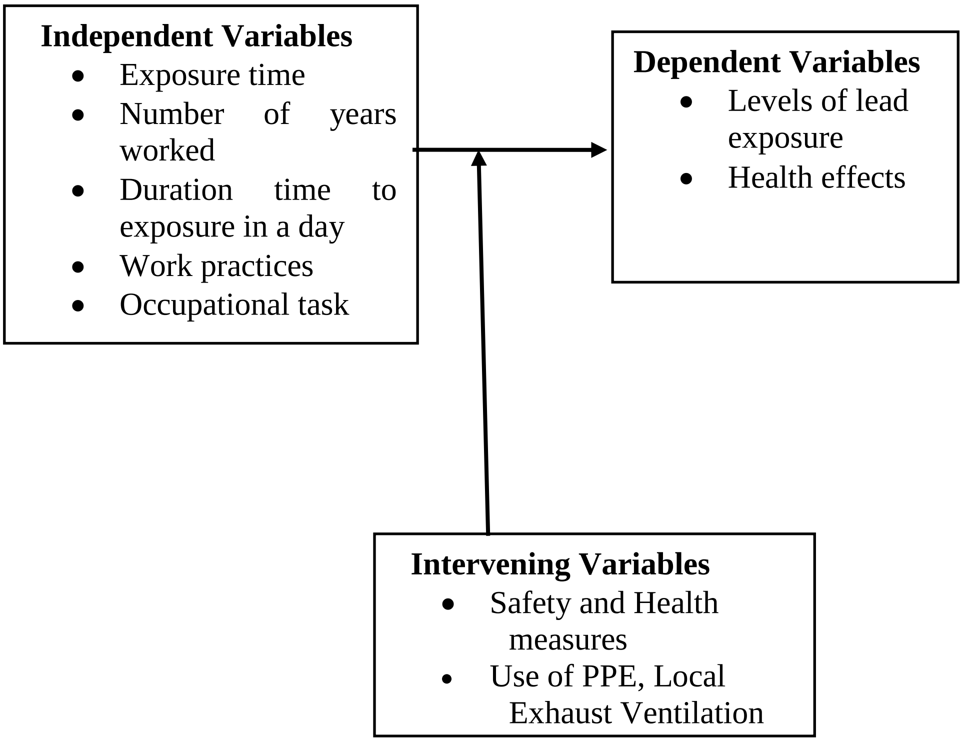


Figure 1.1: Relationship between Independent and Dependent Variable

CHAPTER TWO

LITERATURE REVIEW

2.1 Theoretical Principles

This chapter reviews literature based on national and international guidelines and practices on the sources and levels of occupational exposure to Lead and explored effectiveness for occupational Lead exposure control measures based on assessing the Occupational Safety and Health status of Lead exposure at workplaces.

Lead is soft and heavy with a density of 11.34g/cm^3. It is easily malleable. The malleability means that it can be bent, cut, shaped, pulled and capable of being hammered into thin sheets (Ajayi *et al*., 2014). Furthermore, Lead is ductile since it can easily be drawn into thin wires or rods. In metallic state, Pb is essentially a shiny grey – blue surface when freshly cut, but upon oxidation in the presence of air, it turns into dull dark grey solid (WHO, 2010).

2.1.1 Abundance of Lead

Lead (Pb) is a natural element that occurs in the earth’s crust. The abundance of Pb in the Earth's crust is estimated to vary from 13 to 20 parts per million (ppm) and the most common ore of Pb is galena or Lead sulfide (PbS). Other ores of Pb are anglesite, or Lead sulfate ($PbSO_4$); cerussite, or Lead carbonate ($PbCO_3$); and mimetite ($PbCl_2$, $Pb_3(AsO_4)_2$) (WHO 2010). It has become widely distributed in the biosphere in the past few thousand years. This has almost entirely been as a result of human activities (WHO, 2010). Millions of tons of Pb are produced or handled annually (Patrick, 2006). For instance, Pb that is used in the industries comes from primary sources such as mining of ores that include Pb: sulphide, sulphate, carbonate, chloroarsenate, and chlorophosphate or from secondary sources from recycled scrap metal and Pb batteries (CDC, 2005).

Ultimately, Pb is among the top metals used all over the world in several operations such as mining, smelting, refining and manufacturing. Inorganic Pb is mainly found in paints, Lead-acid batteries, Leaded plumbing systems, soil, dust and various consumer products is less toxic than organic Pb. Organic Pb that is Tetraethyl Pb and Tetramethyl Pb was used in Leaded gasoline (ASTDR, 2007). The organic forms of Pb are extremely dangerous, as they are absorbed directly into the skin, highly toxic to the brain and central nervous system (WHO, 2010).

2.1.2 Lead in Ambient Air

In most countries, Pb concentrations in ambient air have significantly reduced after the phase-out of Leaded gasoline. However, Pb can still enter the air from other sources. Open burning of waste to reduce the volume or obtain metals from waste is one of the main sources by which Pb is introduced into the environment in regions where waste is poorly managed. In addition, Pb is found in various household products and in other components that end up in the municipal waste or in uncontrolled waste deposits. The electric and e-waste may also be directly sorted and eventually taken to informal sector where they are used to produce diverse products. thereby contaminating the immediate work environment with Pb. (WHO, 2010).

2.1.3 Exposure Pathways of Lead into the Human Body

Lead exposure is unavoidable because of its persistence in the environment and wide usage in everyday life. Figure 2.1 shows the exposure pathways and various parts of the body where Pb is stored, including the excretion routes. Consistent with WHO, (2015) the general population exposure to airborne dust containing Pb particles and from contaminated food or water is that 15.0– 30.0% is through inhalation and 70.0–86.0% ingestion.

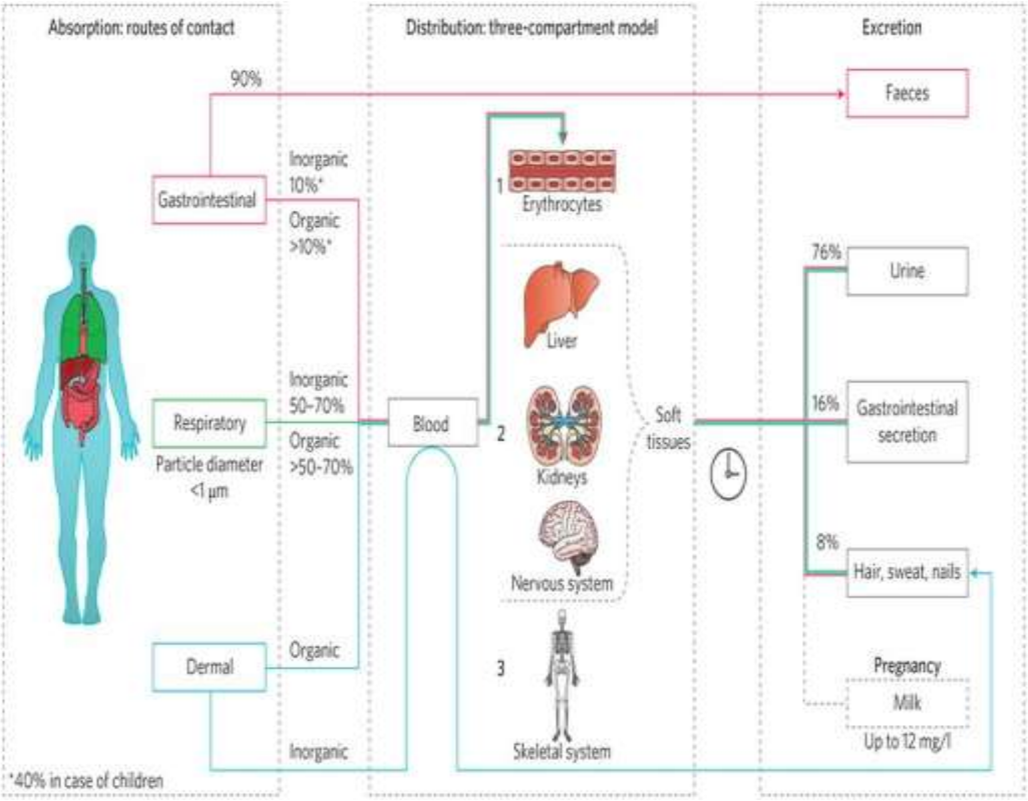


Figure 2.1: Schematic Overview of Absorption, Distribution and Excretion of Pb compounds in the human body

Source: Babayigit *et al*., 2016.

Human beings are exposed to Pb through three routes that include: skin absorption, inhalation and ingestion. The main entry of Pb to the human body is through the respiratory or gastrointestinal tract and is distributed in blood, soft tissues, and bones (Patrick, 2006). For some individuals, the food is the primary source of exposure. Ingestion is the most common route of absorption in children due to peri-oral transfer of Pb to the mouth (Lanphear *et al* 2002).

Organic and inorganic Pb can penetrate through the skin. Studies done by Larese et al 2006 found out that Lead oxide (inorganic Lead) can pass through intact human skin however penetration rate of Pb through damaged skin was nine times greater than through the intact skin. Exposure to Pb can also occur during application of Lead-containing cosmetics such as lip balms especially if lips have wounds.

However, most Pb compounds that can easily penetrate through the intact skin are those in additives found in Leaded gasoline (ASTDR, 2007).

Lead exposure through drinking water is mainly because of other sources such as Lead pipe, solder, cisterns, paints, atmospheric fallout into uncovered reservoirs, and industrial sewage (John, 2012). Moreover, Pb contamination has been found to be high in water from plastic pipes because Pb stearate is used as a stabilizer in the manufacture of polyvinyl chloride plastics. Sources of Pb in dust and soil include Pb that falls to the ground from the air, weathering and chipping of Lead-based paint from buildings, bridges, and other structures. In addition, Pb may enter streams, rivers, and lakes due to soil erosions. Lead can remain stuck to soil particles or sediment in water for many years, penetration of Pb from the soil into the groundwater is, however, unlikely unless the rain falling on the soil is acidic (ASTDR, 2007).

The sources of Lead exposure are greatly varied, in communities where Pb is processed, air emissions are of major concern (Karrari *et al*., 2012).

According to WHO, (2015) only 10.0% of the swallowed Pb is absorbed into the body whereas the rest is excreted. A great proportion of about 30.0% to 40.0% of inhaled Pb is absorbed through the lungs. 90.0% of absorbed the inorganic Pb in the blood stream, will be deposited into the body tissues and bone structures, 0.001% in the plasma, 0.4% in the blood cells, and will inhabit in the body for thirty-six days, 7.6% will be in the soft tissue, and will remain in the body for 40 days, 23.0% in the trabecular bone and will be in the body one year. The cortical bone will have 69.0% of Pb and will remain in the body for decades while 10.0% will be predominantly excreted via the kidney and small amounts in sweat, feces and breast milk (Hu *et al.*, 2007)

2.1.4 Occupational Exposure

Occupation Pb poisoning dates to mid-19th century and was a common problem in the United Kingdom. Subsequent deaths of several employees in Pb processing industries in 1882, Lead to a parliamentary enquiry to investigate the working conditions of the workers (Azizi, M. H., & Azizi, F. (2010).). The investigation resulted in promulgation of the Factory and Workshop Act mainly for Prevention of Lead Poisoning. The Act was a requisite for Pb factories to conform to basic standards, such as provision of adequate ventilation and protective clothing. Especially since high concentration of Pb in the blood of factory workers was lined to extensive exposure to Pb and use of dirty hands (Ho *et al.,* 1998). Over time, stricter controls and improvements have assisted to ensure that occupational Pb poisoning is less prevalent in highly industrialized countries. However, occupational exposure to Pb in developing countries is rampant (Schirnding, 1999).

In England, enactment of the Occupational Safety and Health Administration (OSHA) Act in 1993 minimized Pb exposure among construction workers and bridge painters. A study among 84 bridge painters indicated that these workers were exposed to Pb during several job tasks performed during the workday that involved sanding, scraping, and blasting. In this study, Pb concentration in ambient air, hand wipe samples and blood samples were determined and the mean air Pb levels over the working period were most predictive indicator of blood Pb levels (Rodrigues *et al.,* 2011).

Research conducted by Karri *et al*., (2008) among workers of Pb bullets and battery manufacturing companies in Iran reported that employees in this industry were continually exposed to Pb contamination. A review by Mañay *et al.,* (2008) in Uruguay revealed that 60% exposed workers to Pb poisoning above 40 µg/dL were working in battery or metallurgy factories. In Brazil, it was reported that Pb exposure occurred mainly in Pb-acid battery producing and recycling plants however exposure also occurred in plastic, ceramics, and rubber industries where Pb pigments are used. In addition, small re-conditioning battery workshops and medium size secondary smelting plants have been found to be responsible for the most occupational Pb poisoning cases in Brazil (Paoliello *et al.,* 2007).

A comprehensive review of high air Lead and blood Lead levels (BLL) in battery workers have been reported across the developing nations (Gottesfeld *et al*., 2011). Gebrie *et al.,* (2014) established elevated BLL among unskilled construction workers in Jimma, Ethiopia. The study found a significantly low mean BLL of 29.81 ± 10.21 μg/dL in the unexposed group when compared to 40.03 ± 10.41 μg/dL in the exposed group. The unskilled construction workers were more likely exposed to Pb than the general population. Workers who were at the risk of exposure to Pb were mainly in battery manufacturing industries, demolition work, welding, pottery and ceramic ware production, also in small operations such as automobile radiator repairs and the production of jewelry and decorative items, and more often those in a home-based occupation that involved women and children, (da Silava, 2019)

There are numerous activities in the informal sector in Kenya that involves application of Pb and its products (Njoroge *et al.*, 2008). These activities include spray painting, panel beating, metal cutting and welding as well as motor vehicle mechanics. The highest levels of BLL were noted amongst the spray painters. This was attributed to lack of proper ventilation mechanisms in the workplace and workers not taking preventive measures. There was lack of awareness among workers about Pb exposure and monitoring and regulation were also lacking.

2.1.5 Health Effects of Lead Exposure

About 23.0 – 26.0% of inhaled Pb dust is deposited in the lungs and almost 95.0% of that goes into the bloodstream (Kastury, 2019). According to Karri *et al.,* 2008, 15.0% of the ingested Pb is absorbed into the bloodstream and is stored in the soft tissues and bones. Approximately 94.0% of absorbed Pb is stored in the bones where it is released causing toxic effects such as kidney damage. The toxic nature of Pb has been known since 2000 BC. Lead poisoning was a common phenomenon in Roman times, due to the use of Pb in the plumbing systems, earthenware containers, wine storage vessels, and the use of Leaded syrup called Sapa, that sweeten wine (WHO, 2010).

2.1.5.1 Lead Exposure and the Central Nervous System

Lead is a divalent cation that strongly binds to sulfhydryl groups on proteins. One of the most affected organs in the human body is the central nervous systems (CNS) (Needleman, 2004). Many of toxic effects of Pb are due to its ability to mimic and compete with calcium (Ca). It has capability of competing with Ca for binding sites on cerebellar phosphokinase C and thereby affecting neuronal signaling (Markovac *et al.,* 1988.).

Although, both adults and children develop neurotoxicity, children appear to be more vulnerable (WHO 2010, Patrick, 2006). Diminished Intelligent quotient (IQ) level, slowness of performance, excessive sleep, pain and tenderness in muscle have been observed to increase with rising BLL (WHO, 2010; CDC wonders &WHO, 1999; Sullivan *et al*., 2001). Extensor muscle palsy with “wrist drop” or “ankle drop” has been recognized as a common clinical manifestation of neurotoxicity (WHO 2010, Patrick, 2006; Landrigan, 1990). A review done by Kristensen, (1989) concluded that there were increased incidence of cerebrovascular diseases among individuals occupationally exposed to Pb. Chronic neuropathy which may progress to kidney failure, is largely among workers with BLL exceeding 60 μg/dL (WHO, 2010; Patrick, 2006; Gidlow, 2004).

2.1.5.2 Lead Exposure and Kidney Failure

Lead poisoning may lead to impairment of the function of proximal convoluted tubules thereby causing Kidney failure (Rubin, 2008). Moreover, Pb poisoning of the kidneys inhibits the excretion of uric acid predisposing one to gout (Lin *et al*, 2001).

2.1.5.3 Lead Exposure and Thyroid Function

Thyroid function might be depressed because of intense long-term exposure to Pb (Dundar *et al.*, 2006). Studies have associated decreased iodine intake by the thyroid gland to Pb poisoning. This is because free thyroxine in serum correlated negatively to Pb exposure among the group of workers of African origin (Dundar *et al*., 2006)).

2.1.5.4 Lead Exposure and Fertility

Chronic high BLL of >40 μg/dL or >25 μg/dL in men seems to reduce fertility through low sperm volume. There is also increased risks of spontaneous abortion, reduced fetal growth and preterm delivery. Maternal BLL of approximately10 μg/dL have been related to increased risks of hypertension in pregnancy, spontaneous abortion, and impaired neurobehavioral development in the offspring. Higher maternal BLL have been linked to reduced fetal growth; there is still however uncertainty regarding correlation to malformations and the dose–response (Bellinger, 2005).

2.1.5.5 Lead Exposure and Anemia

Ashraph *et al.*, (2012) studied the health effects of Lead exposure among Informal sector workers of Express "Jua Kali" in Mombasa County - Kenya that revealed that there is a significant inverse relationship between Pb exposure and hemoglobin levels with 17.6% of exposed workers being anemic. Hsieh *et al.*, (2017) evaluated the association between Lead exposure and anemia risk among factory workers in Taiwan. His results indicated that cumulative exposure to Lead in the workplace was significantly associated with anemia risk.

2.1.5.6 Lead Exposure and Blood Pressure

Elevation of blood pressure has been associated with long-term Lead exposure (WHO, 2010; Patrick, 2006). A review done by Navas-Acien *et al.*, (2007) concluded that there is a causal relation between Pb exposure and blood pressure. There is an increased incidence of cerebrovascular diseases among workers occupationally exposed to Pb. Accumulation of Pb in the kidneys of workers is associated with hypertension.

2.1.5.7 Lead Exposure and Cancer

The International Agency for Research in Cancer (IARC) has classified Pb as a 'possible human carcinogen based on sufficient animal and human data. Although a few studies have been published, showing the overall weak evidence for Pb carcinogenicity and mostly reported lung, stomach cancer and gliomas (Steenland *et al.*, 2000). Nonetheless, large doses of Pb compounds have been observed in the development of Kidney tumors among rats (ASTDR, 2007).

2.1.5.8 Mortality and Modality due Lead Exposure

From the routinely collected data on mortality rate between 1981 - 1996 and the hospital admission statistics data of 1992–1995, only one death and 83 hospital cases were reported (Elliott *et al.,* 1999). Mortality and hospital admission cases in England due to Lead poisoning were rare, although such cases seemed to occur and some were associated with Pb poisoning. The half-life of Pb in the bone is more than twenty years while in blood is 25-28 days (ATSDR, 2005; Kosnett, 2001, & Patrick, 2006). The National Toxicology Program (NTP) concluded that there is sufficient evidence for adverse health effects in children and adults for BLL <5 µg/dL (CDC, 2012). Figure 2.2 depicts reduction of BLL from 1960's to now (CDC, 2012). There is no known safe level of exposure to Lead, health effects of Lead exposure are major WHO, 2017.

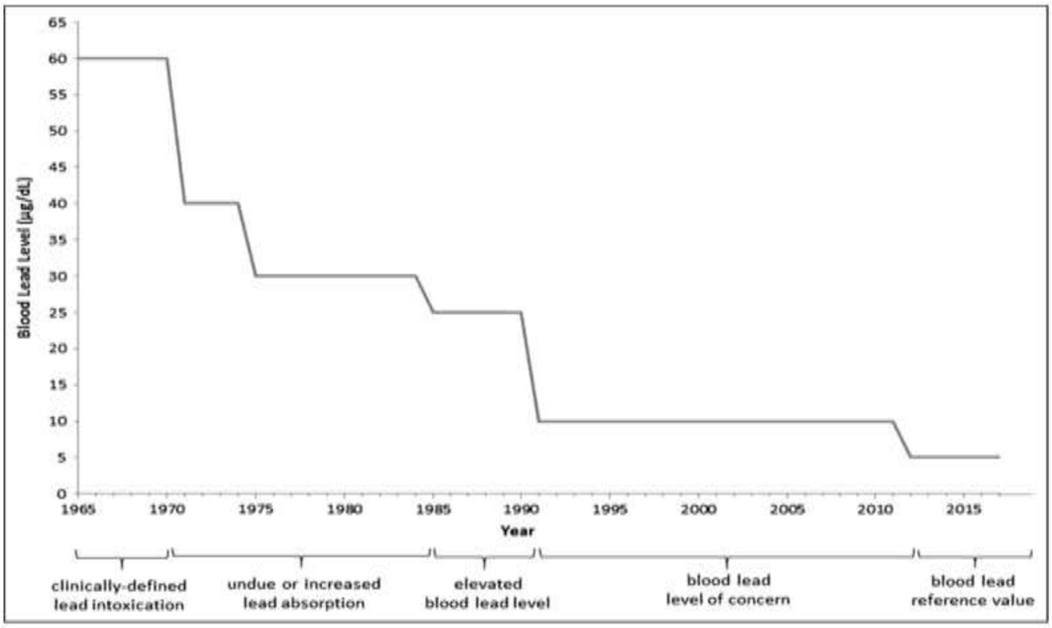


Figure 2.2: BLLs over Time

Source: (Ettinger *et al.,* 2019)

2.2 Legal and Regulatory Framework

Various national and international legislations/ guidelines governing environmental and occupational Pb exposure have been established. The WHO air quality guidelines for annual airborne Pb limits for European states should not exceed 0.5 µg/m^3 (WHO, 2010). The National Institute of Occupational Safety and Health (NIOSH) and the CDC have set a Recommended Exposure Limit (REL) of 50 micrograms per cubic meter (µg/m^3) of Pb air for a Time Weighted Average (TWA) of an 8-hr. This value should be maintained so that workers' BLL remains below 60 µg/dL (Barsan, *et al*., 2009). The set US OSHA Permissible Exposure Limit (PEL) of airborne Pb of 50 µg/m^3 for workers at Time weighted Average (TWA)., which is hours averaged working period. In general and construction industry, the required US OSHA, PEL action level of Pb exposure for an average of 8-hr is 30 µg/m^3. OSHA dictates regular determination of BLL for those exposed to air Pb concentrations at or above the action level of 30 µg/m^3 for more than 30 days per year. National Research Council. (2013).

The American Conference for Governmental Industrial Hygienist (ACGIH) has set a threshold limit value for a time-weighted average (TLV/TWA) of 50 µg/m^3 for Pb in workplace air (except for Lead arsenate), National Research Council. (2013). The ACGIH has set a Biological Exposure Indices (BEI) for BLL of 30 µg/dl. On the contrast, the CDC [2010] recommended a precautionary approach, noting that a BLL ≥5 µg/dl in a pregnant woman indicates exposure to Pb levels that exceeds that of most women of childbearing age in the USA. The recommendation is to keep BLLs as low as possible of the pregnant women and to remove occupationally exposed pregnant women, from Lead-exposed work areas if BLLs are ≥10 µg/dL ([CDC, 2010). The CDC/NIOSH reference BLL for adults is 5 µg/dL (CDC, 2013h)

2.2.1 The Occupational Safety and Health Act, 2007

The Occupational Safety and Health Act, 2007 (OSH, 2007) requires that every occupier should ensure the safety, health and welfare at work of all persons working in his workplace.

The occupier should also provide information, instruction, training and supervision as is necessary to ensure the safety and health at work of every person employed informing all persons employed on any risks and imminent danger, they are likely to be exposed to while at work. Appropriate risk assessments in relation to the safety and health of persons employed and, on the basis of these results, adopt preventive and protective measures to ensure that under all conditions of their intended use, all chemicals, machinery, equipment, tools and process under the control of the occupier are safe and without risk to health and comply with the requirements of safety and health provisions in this Act

2.2.1a Factories and other Places of Work (Hazardous Substances) Rules

The Factories and Other Places of work (Hazardous Substance) Rules, L.N. No. 60/2007 a subsidiary of the Occupational Safety and Health Act (OSHA), Kenya applies to a work environment where workers are likely to be exposed to hazardous materials. The rules, basically require the employer to put in place mitigation strategies that will prevent employees from getting exposed to hazardous substances in general and where these are not feasible, appropriate PPEs should be provided These rules also stipulated the occupational exposure limits (OEL) for hazardous substances. The procedure for safe handling, use and disposal of hazardous substances is also established. The Kenya Standards for occupational Pb exposure has been set at 150 µg/m^3 TWA OEL-CL (The Factories and Other Places of work (Hazardous Substance) Rules, L.N. No. 60/2007)

2.2.1b The Factories and other Places of Work (Medical Examination) Rules

Medical Examination rules, L.N. No. 24/2005 applies to workplaces where employees are engaged in occupations that expose them to hazardous substances such as Pb that might harm their health. The rule includes detailed medical surveillance procedures and specifies occupations requiring medical examinations of workers at the employer’s cost.

Table 2.1: Occupational Air Quality Standards for Lead

Jurisdiction or Advisory Body	**8 Hour Limit Value Inhalable Lead µg/m^3**
Kenya – Hazardous Substance Rules	150
USA- NIOSH	50
OSHA (US)	50

Source: The Factories and Other Places of work (Hazardous Substance) Rules, L.N. No. 60/2007 and The National Institute of Occupational Safety and Health

Table 2.2: Environmental Air Quality Standards for Lead.

Agency	**Lead Limits in the Air**
WHO Air Quality Guidelines	Annual Average is 0.5 µg/m^3
The EMCA (1999)	Annual Average is 1.0 g/m^3
Air Quality Regulations 2014	Annual Average is 1.0 µg/Nm^3

Source: WHO 2010, EMCA 1999 and Air Quality Regulations of 2014

2.3 Previous Work Related to the Study

2.3.1 Lead Exposure among Workers in the Informal Sector

Ashraph, *et al.,* 2012 studied the adverse health effects of Pb exposure in workers in the Informal sector of the Express “Jua Kali” in Mombasa County. Correlation design was used to establishing the nature and degree of relationship between Pb exposure as the independent variable, BLL, kidney function and hemoglobin levels as the dependent variable. The results indicated that awareness of workers about Pb and its effects was low despite all the international efforts to ban or reduce Pb levels in products and the environment since the 1970s. However, the study revealed that there was a significant improvement of related awareness amongst workers with a tertiary level of education (18.0%) compared to 5% of those with primary education. The group that was most exposed to Pb, were radiator repairers over 80.0% of them had high BLL, 50.0% had impaired kidney function, more than 30.0% with hemoglobin less than 13 g/dl. This is because these workers were heating the Pb until it melts to vapour and in the process, they inhale the vapour (Olsen, 1991).

The study concluded that there was limited level of awareness of Pb and its effects among informal sector workers, especially those of lower cadre. There was also a significant positive relationship between Pb exposure and BLLs, with 13.5% of the exposed workers having high BLL (>10 μg/dl). The study recommended the following to protect "Jua Kali" workers from over exposure to Pb: Education on Pb exposure and its effects. The government should provide free or subsidized appropriate PPEs such as facial mask, gloves, gowns, water for washing PPEs and bathing. They should be assisted to set up engineering controls and regular medical examination undertaken. Furthermore, a specialized medical center such as a referral for the diagnosis and management of Pb and other heavy metal toxicity should be established. Lastly, a detailed study should be done to assess the actual amounts of Pb levels that workers are exposed to using personal air samplers.

In 2019, Odongo *et al.,* conducted a study on the risk of high BLLs among informal sector automobile artisans: a case study of Nakuru town, Kenya. The data was collected using structured questionnaire and laboratory analysis. Sixty purposively sampled participants that included 30 artisans and 30 age-matched control subjects, were assessed. Lead levels in blood samples were analyzed using NIOSH method 8003. The automobile artisans had four times odds (Odds ratio = 4.0; 95.0% CI = 1.37 – 11.70) of having high BLL compared to the control subjects. The study concluded that the informal automobile repair workshops pose risks of higher BLL than the artisans. There is, therefore, need for occupational safety and health monitoring and intervention programmes in the informal sector to curb such health risks.

2.3.2 Lead Exposure in the Formal Sector

Were *et al.,* (2012) studied Pb exposure among workers in one Pb recycling plant and battery manufacturing plant. The sampling locations taken as the representative of the workers' airborne Pb exposure. Portable air sampling equipment's were calibrated with a rotameter, to maintain the flow rate of 2 l /min and fitted with a mixed cellulose-ester membrane filters with 0.8 μm pore size and 37mm in diameter. Air sample pump were set on a tripod stand 1.5 m above the ground in each work areas to approximate the average breathing zone level of workers in a standing position. Filters were analyzed as per NIOSH Method 7082. A flame atomic absorption spectrophotometer (FAAS) was used for the analysis of air samples.

Mean Pb results for lead acid battery recycling plant was 427 ± 124 µg/m^3 while the office area had Pb level of 59.2 ± 22.7 µg/m^3. At the lead acid battery manufacturing production areas, the mean Pb levels were 349 ± 107 µg/m^3 whereas the office had 55.2 ± 33.2 µg/m^3. The study recounted inadequacy in engineering controls, work practices, respirator use and personal hygiene that was responsible for elevated airborne Pb levels. Improved engineering controls, good work practices, respiratory protection and personal hygiene were recommended.

Were *et al.,* (2014), studied the relationship between Pb exposure and Blood Pressure (BP) among workers in diverse industrial setting in Kenya done in April 2011 to April 2012. The correlation between airborne Pb in breathing zone and BLLs in 233 production workers at six different industrial sites were evaluated, work practice and safety conditions of workers was also studied. Air and blood samples were collected and analysed for Pb using AAS. The BP was measured using a standard mercury sphygmomanometer.

Lead was 126.2 ± 39.9 µg/m^3 in scrap metal welding areas, 183.2 ± 53.6 µg/m^3 in battery recycling, 76.3 ± 33.2 µg/m^3 in paint manufacturing. The above concentration of airborne Pb exceeded the U.S. OSHA8-hr TWA PEL for Pb of 50 µg/m^3. The study recommended engineering controls, work practices, and improved personal hygiene to reduce Pb exposures.

CHAPTER THREE

MATERIALS AND METHODS

3.1 The Study Design

This section discusses the research methodology adopted in order to achieve intended study objectives. In particular, it identifies the research design, target population, sampling procedure, research instruments, research validity and reliability, and data analysis. The study was undertaken to evaluate airborne Lead (Pb) exposure among informal sector workers in Kamukunji Jua kali Sheds in Nairobi County. The research design was both descriptive and experimental.

Field surveys and related investigations began in October 2016 and ended in July 2019. Authorization and approvals to access the sampling sites were obtained from the Jomo Kenyatta University of Agriculture and Technology and the Chairman of Kamukunji Jua Kali Association (Appendices-XIII and XIV, respectively). Since no blood samples were to be collected, approval from NACOSTI was not obtained.

Sampling employed purposive sampling that involved collection of airborne Pb levels in triplicates from the thirty-four (n=34) production areas (sheds), in Kamukunji “Jua Kali” Sheds and the control areas (n=2) that were free from any known Pb related activities in Ongata Rongai, 22.0 km from Nairobi County, the airborne Pb samples were analyzed using flame atomic absorption spectroscopy (FAAS). The data on working conditions, safety and health measures was obtained using observations, interviews and questionnaires.

3.2 Study Area and Population

The study was conducted in Kamukunji “Jua Kali” sheds, located in Pumwani division, Nairobi East Sub-County, Nairobi County. The site is approximately 2 km from the Nairobi Central Business District (CBD) (Figure 3.1). The current population is over 5,000 people and is dominated by micro (1-3 workers) and small enterprises (4-10 workers) (Njeri 2008). The Municipal Council Authorities that is currently the County officials initially used Health ACTS to control the cluster expansion while demolishing makeshift structures erected by the artists.

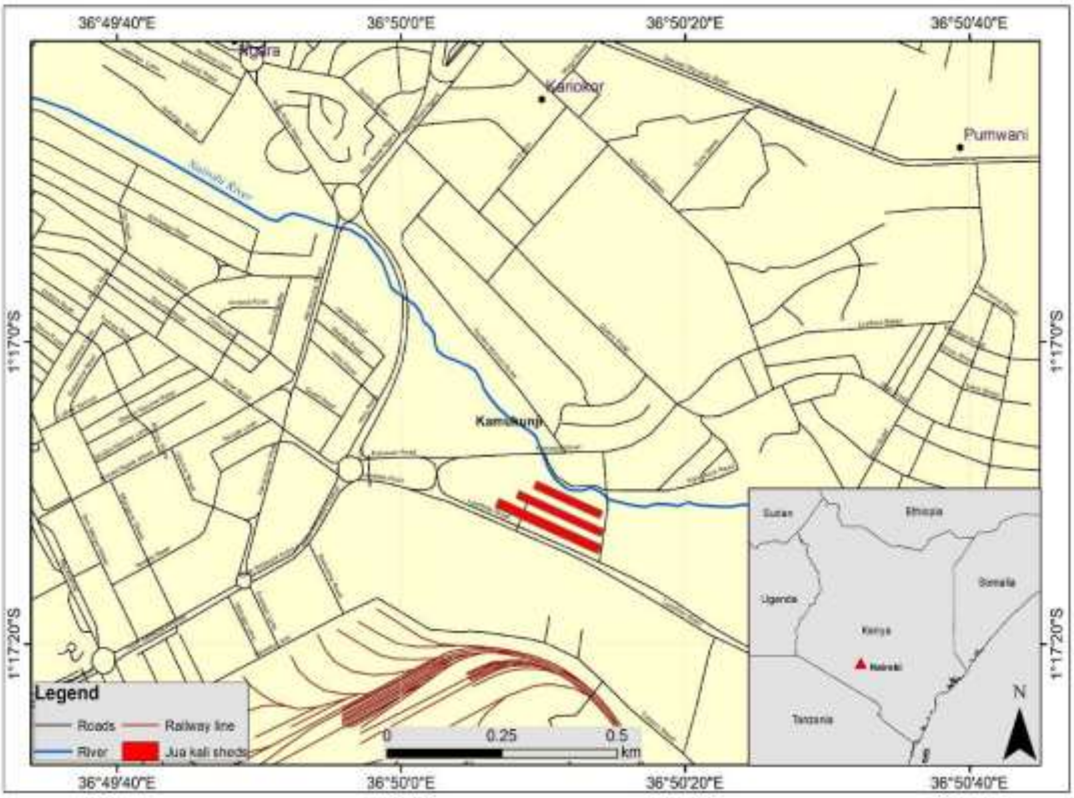


Figure 3.1: A Map showing Kamukunji "Jua Kali" Sheds Nairobi

Source: Department of Geology University of Nairobi.

A shed could house as many as three different entrepreneurs. In most cases, each shed was occupied by about 10 artisans (Nelima 2015). Accessibility to the area could be from Gikomba Market, Sakwa Road and Secondary Road from Landhies. However, movement around the market itself was very cumbersome due to the narrow paths without well-defined entrances created by the traders. Additional makeshift structures have since been built haphazardly at different grounds as a result of increased population within the area (Nelima, 2015).

3.3 Sampling Method

Sampling method involved collection of airborne Pb in triplicates from each shed and control areas using air sampling pumps. The model used were SKC, AirChek sampler Model 224-52 air sampling pumps and Apex 2std I.S personal sampling pumps. It also involved use of questionnaires, observations and interviews.

3.4 Sample Size Determination

The study adopted the approach of specifying the precision rate and confidence level of the estimate desired and then determined the sample size necessary to insure it (Kothari, 2004).

Due to impossibility of covering the entire population, the researcher administered instruments on sample units which were objectively constituted. The Formula for determining the sample size was*:*

$$n_f = \frac{Z^2 \times N^2 \times p \times q}{(N-1)\,d^2 + Z^2 \times p \times q} = 34$$

Where: n_f = desired sample size (n < 10,000)

- Z= the standard deviation at 95.0% confidence level
- Confidence level of the normal distribution curve=1.96
- p=the proportion in the target population estimated to have characteristics being measured (Default value of 50.0% assumed since p is unknown)
- q=1-p= 0.5
- d=the level of statistical significance set (thus accuracy desired at the acceptable
- Error of +/- 0.05

Using a sampling frame of 37 sheds, our desired sample size n_f can be given by

$$n_f = \frac{196^2 \times 37^2 \times 0.5 \times 0.5}{(37-1)\ 0.05^2 + 196^2 \times p\ \times\ q} = 34$$

The sample size = 34 sheds and two control areas.

Out of the 37 sheds labelled 1-37, thirty-four (n= 34) sheds were purposively selected and clustered according to the various activities that were carried out within the sheds. These activities were perceived to emit Pb in the air as reported by Ashraph *et al*., 2012 and Njoroge *et al.,* 2008. These sheds were 1-4, 6-9, 11-13 and 15- 37 and had only one Leader. Sheds number 5, 10 and 14 were excluded from this study.

3.5 Research Instruments

3.5.1 Sampling of Airborne Lead

The method used to sample airborne Lead samples was in accordance with the National Institute of Occupational Safety and Health (NIOSH) USA 7082 (NIOSH, 1987). Workplace area airborne Pb was collected using SKC, AirChek sampler Model 224-52 air sampling pumps and Apex 2std I.S personal sampling pumps. Air sampling was done in thirty-four (n = 34) production areas (sheds) according to the activities that were conducted within the sheds during working hours. This was collected as follows: in twenty-three sheds (n = 23) that included shed 1 to 4, 7 to 9, 12, 13, 15, 18, 19, 20 to 26 and 28 to 31 that carried out fabrications of various metallic items; in seven sheds (17 and 32 to 37) that were involved in grinding, heating and soldering activities then in two sheds (11 and 27) involved in welding activities and sheds 6, 16 that was only involved in spray and painting operations, two control areas thus open private library and open field. Three sets of samples were collected in each shed and the control sections in different days, a total of 102 samples were collected from the sheds and 6 from the control.

The operating pumps batteries were fully charged before sampling. This was to ensure the pumps were able to run throughout the sampling period. The air sampler, cellulose membrane filter papers of 37 mm in diameter and 8 µm pore size were preconditioned in a desiccator for twelve hours. In order to avoid contamination, clean forceps were used to handle the cellulose filter papers. The equipment was assembled by placing the filter paper in between the support ring and the cover. The sampling tube (flexible by design) was then connected to the pump. The pump was calibrated using a flow meter (rotameter) as per the manufacture’s instruction.

The representative airborne Pb samples were collected by placing the air sampler pumps onto a stand and the sampling head mounted to the workers breathing zone level. Since most of the workers were working at sitting or crouching position the pumps were placed approximately 1 m from the ground to collect airborne Pb samples in the workers’ breathing zone. The air sampler was set to have a constant flow rate of 2 liters per minute. This was subsequently checked periodically during the sampling period of 8-hours’ time weighted average to ensure a constant flow rate was maintained. The filter papers were then sealed in cassette filter holder for storage prior to chemical analysis of airborne Pb.

Plate 3.1: Air sampling in one of the sheds.

Source: Author

3.5.2 Determination of Airborne Lead

Analysis of the loaded filter samples was carried out at Mines and Geology Laboratory in industrial area Nairobi County. Appropriate personal protective equipment (PPE) was worn before carrying out the analysis. Stored samples in the cassette filter holders together with the blanks were then transferred to clean 50 ml beakers. Three (3.0) ml of concentrated nitric acid (conc HNO_3) and 1.0 ml of 30% hydrogen peroxide (analytical grade) was then added to each beaker.

The samples and blanks were thereafter digested on a hot plate set at 140^0 C and covered using a watch glass to avoid excessive evaporation. This procedure was repeated twice with addition of 2.0 ml conc HNO_3 and 1.0 ml of 30% H_2O_2 each time the volume reduced to 0.5 ml. After digestion the beakers were washed with 5.0 ml of 10% HNO_3 and the sample evaporated to dryness, cooled and the residue dissolved with I.0 ml conc. HNO_3. The solution was filtered and transferred to 10 ml volumetric flask and diluted to the mark prior to FAAS analysis. The Pb standards were prepared by diluting the commercial atomic absorption spectrometry stock Pb standard solution of 1000 µg/mL using de-ionized and distilled water. A series of working standards ranging from 0.25 to 20 µg/ml Pb were then prepared. A mono-elementary hollow cathode lamp for Pb that operated at a recommended current was used as a light source together with optimized conditions for FAAS (Table 3.1)

Table 3.1: Optimized conditions for Flame Atomic Absorption Spectrophotometer

Conditions	Parameters
Lamp current (mA)	6
Measurement time (s)	1.0
Flame	Air – Acetylene
Wavelength (nm)	283.0
Slit width (nm)	1.0
Oxidant flow rate (L/min)	1.5
Sensitivity (µg/L)	0.110
Detection limit (µg/L)	0.020
Air flow rate	7ml per minute

Aqueous standard solutions with appropriate concentrations for Lead analysis were run using the FAAS after plotting a standard calibration curve. The concentration of Pb in the samples were subsequently assayed in triplicates using FAAS at optimized operational conditions shown in Table 3.1. This concentration was obtained directly from the standard calibration curves after correction of the absorbance for the signals from appropriate reagent blanks for Lead.

3.5.3 Calculations of Lead in Air

Lead in air concentrations were calculated as per the formula below.

$$C = \frac{C_s V_s - C_b V_b}{V} \quad , \text{mg/m}^3$$

Where C- Concentration

- C_S- corresponding concentrations (µg/mL) of Lead in the sample
- V_S- the solution volume (mL) of the sample
- C_b - corresponding concentrations (µg/mL) of Lead in the blank
- V_b - the solution volume (mL) of the blank
- V – Volume of sampled air during sampling.

NB: µg/mL = mg/m

All airborne Pb concentrations were then expressed as microgram (µg) per cubic meter (m^3) of air over an 8-hour Time Weighted Average (TWA).

3.5.4 Quality Control and Assurance

Quality control and assurance was considered by ensuring that all the glassware used in the analysis were cleaned with concentrated nitric acid and rinsed thoroughly with de-ionized and distilled water before use. Reagents used throughout the analysis were of analytical grade. A series of working standards were prepared ranging from 0.25 – 20 µg/ml Pb by adding aliquots of calibration stock solution to 100 ml volumetric flasks and diluting with 10% nitric acid (HNO_3). Working standards alongside the blanks and samples were analyzed.

After every ten samples analyzed, a standard was aspirated to check for the instrument drift.

Inter-laboratory comparison was done by selecting a set of five samples at random and analyzing Pb in each of the samples separately using Varian – Agilent technologies AAS equipment of the Associated Battery Manufactures and Mines and Geology AAS at a wavelength of 283.0 nm. The correlation coefficient obtained between the two sets of samples was 0.9660 done using STATA 13.0. This showed a very high positive correlation between the two sets of results and this suggestedthat the results were consistent.

3.5.5 Assessment of Levels of Compliance

Assessment of level of compliance of Lead in air of the workers' environment and that of the standards was done by comparing the airborne Lead levels obtained from this study and those of the set Permissive Exposure Limit (PEL). This study considered the Kenya workplace airborne Pb standard of 150 $\mu g/m^3$ Time Weighted Average (TWA) OEL-CL stipulated by the Factories and other places of work Act (Hazardous Substances), rules of 2007. The levels were also compared with the international workplace airborne Pb PEL of 50 $\mu g/m^3$ TWA of 8-hr set by the US OSHA. (US OSHA, 2002).

3.5.6 Assessment of Occupational Safety and Health Control Measures.

Information on occupational safety and health control measures was captured using questionnaires, interviews and observations. Questionnaires were given to permanent workers who were also the Shed Leaders, where long-term exposure to Pb was assumed. The captured data included: gender of the respondent, approximate age, level of education, how long the respondent had worked in the current workplace, how many hours worked in a day and the number of days worked in a week. In addition, knowledge on Pb exposure, and how the respondent attained that knowledge including concerns of possible exposure to Pb and any related health and safety measures that are put in place, Besides, use of appropriate personal protective equipment (PPE) and enforcement of legislations to curb occupational hazards such as Pb exposure was captured. On medical history, the following information was obtained, medical examinations, routine medical visits related to blood pressure or coughs/ chest pains. Any symptoms or health changes due to the work environment was further considered. Observations were also made during the walkthrough surveys about the occupational safety and control measures to prevent Lead exposure, health aspects, provision of PPE, and personal hygiene.

3.6 Data Processing and Analysis

The raw data was coded and entered into excel spreadsheets prior to the analysis. The collected data was analyzed and summarized in statistical tables and graphs. These also included frequency distribution tables and bar charts. Levels of airborne Pb was averaged for the workers who performed similar tasks in different production areas (sheds). Other relevant statistical techniques such student t-test and One Way Analysis of Variance (ANOVA) were used to compare airborne Lead levels in the target and control group (Appendix V – XII).

3.7 Data Validation

Air sampling equipment used were calibrated with valid certificate of calibration presented in Appendix III & IV. All equipment were calibrated as appropriate. The questionnaire was also piloted to ensure reliability of the research instruments.

3.8 Ethical Considerations

Necessary authorization and approvals to access the sampling sites and carry out field surveys were as obtained from the Jomo Kenyatta University of Agriculture and Technology and the Chairman of Kamukunji Jua Kali Association (Appendices XIII and XIV, respectively). The sheds were coded and the data obtained was strictly confidential and cannot be linked to any respondent in this study.

CHAPTER FOUR

RESULTS AND DISCUSSION

This chapter presents the demographic characteristics of the thirty-four workers (n = 34) who were also the Shed Leaders in Kamukunji informal sector in Nairobi County. These characteristics are summarized in table 4:1 and figure 4:1. In addition, it presents the raw data results (Appendix I and II of airborne Pb levels that were assessed in the 34 production areas (sheds) along with two control areas in Kajiado County. The statistical data is presented in Appendix V - XII. The compliance levels of airborne Pb concentrations in the workers' environment (n = 34) together with occupational, safety, health control measures have further been presented and discussed.

4.1 Demographic Characteristics of the Workers in Kamukunji

The targeted sample size of 34 workers who were also Leaders of the 34 sheds in Kamukunji area participated in the study by filling the pre-tested questionnaires. This gave a response rate of 100%, which is rated as excellent (Mugenda and Mugenda, 2003). The profile of the respondents that included gender, age and education level is summarized as follows:

4.1.1 Gender of Respondents

The study established the gender of the respondents, and the results are given in table 4.1.

Table 4.1: Gender of the Respondents

	Frequency	Percent	Valid Percent	Cumulative Percent
Male	23	67.6	67.6	67.6
Female	11	32.4	32.4	100.0
Total	**34**	**100.0**	**100.0**	

From table 4:1, most of the respondents were males. This is indicated by 67.6% of the respondents who reported that they were males while 32.4% of the respondents were female. The study was hence inclusive of all genders, although the sector is male dominated.

4.1.2 Age of the Respondents

The age of the respondents who participated in this study was evaluated and the results are depicted in figure 4:1.

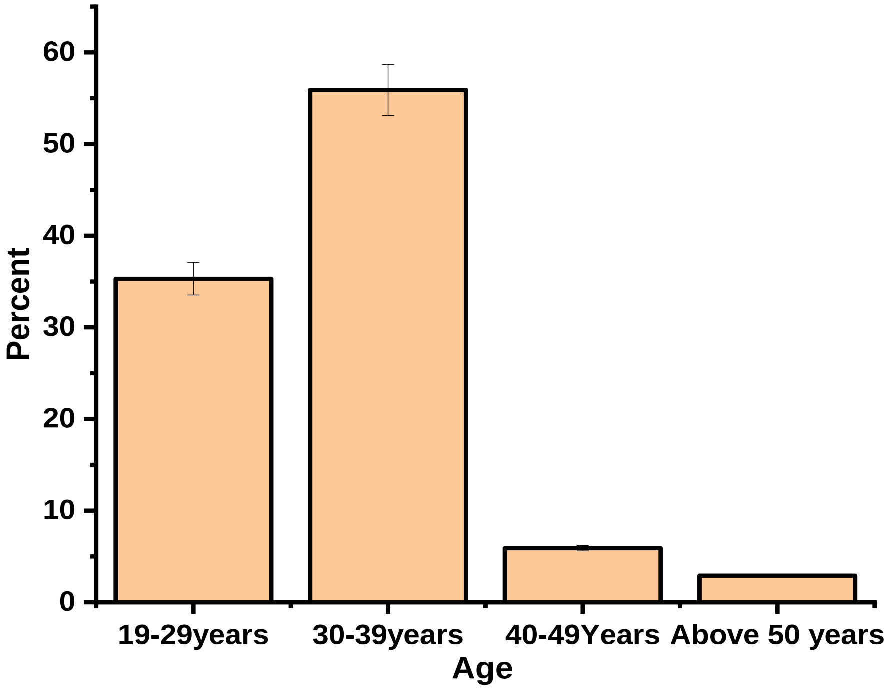


Figure 4.1: Grouped Mean Average of Respondent in this Study

Most of the respondents were aged between 30-39 years of age (55.9%) while 35.3% of the respondents were aged between 19-29 years (Figure 4.1). A small proportion (5.9%) were aged between 40 and 49 years. On the contrast, only 2.9% were aged above 50 years. This shows that the study had all the age brackets and with the majority being young. This could suggest that either the work is too demanding, or health effects may impact most people above 40 years from active work.

4.1.3 Level of Education

The study sought to find out the knowledge on exposure level through the level of education as presented in Table 4:2.

Table 4.2: Level of Education.

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Primary	10	29.4	29.4	29.4
	Secondary	17	50.0	50.0	79.4
	Graduate	7	20.6	20.6	100.0
	Total	**34**	**100.0**	**100.0**	

The study established that more than 50.0% of respondents had secondary education, 29.4% had received primary education while only 20.6 % of these workers were graduates. This demonstrates that the informal economy in Kenya has the potential of attracting workers with a blend of knowledge and skills. Although most workers in this sector acquire on job skills and experiences on job through friends, workmates and relatives. Formal education is therefore not a prerequisite for working in this sector. The entry level to the workplace depends on social networks and this is directly influenced by the knowledge and technology networks in the cluster. In this study, 70.6 % of the respondents had essentially basic education. Previous studies done by Kinyanjui (2008) revealed that out of the twenty case studies, seven had completed secondary level education while six had primary level of education. Five of the respondents were polytechnic graduates while two were university graduates. In terms of skill levels, only five had related certificates from the Directorate of Industrial Training.

4.2 Airborne Lead Levels

The study sought to determine concentration of airborne Pb within the 34 sheds of the study area. The results are presented in figure 4:2 and the corresponding Table 4:3 that show the various activities and the mean LIA results within each shed.

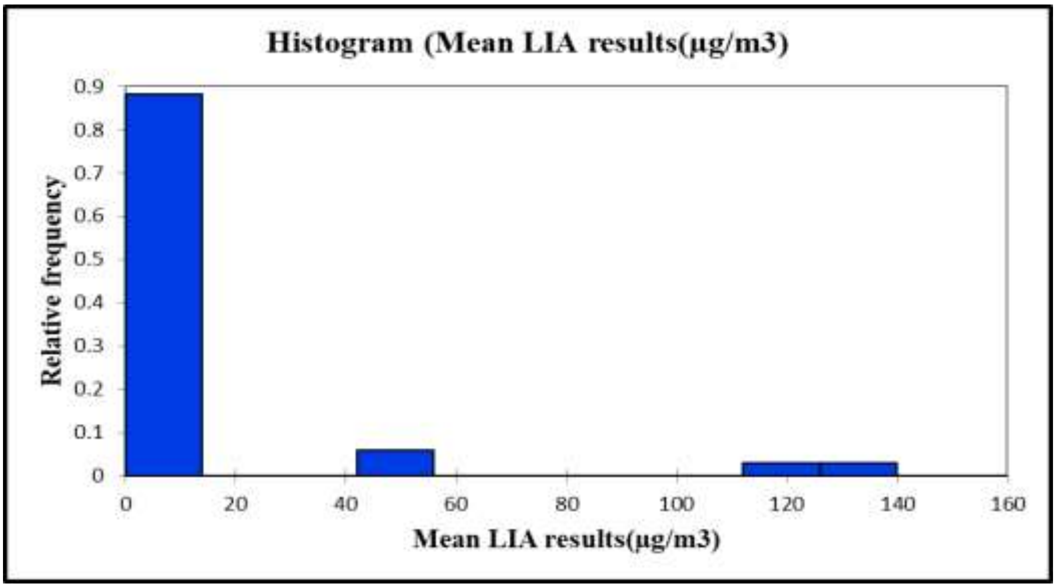


Figure 4.2: Descriptive statistics for the intervals for LIA results in µg/m^3 in different sheds

From figure 4:2, the highest relative frequency is between 0 – 14 µg/m^3. Activities carried out within these sheds were folding, fabrication different metallic products, grinding, soldering and heating. The results shows that most of these sheds had low LIA levels hence low exposure to airborne lead to most of the workers in this sector. Two sheds were within 42- 56 µg/m^3 limits where painting work was done while between 112-140 µg/m^3 were two sheds where welding work was being carried out.

Table 4.3: Mean Airborne Lead Level in different Production Areas (Sheds), (n= 34) in Informal Sector and Control Areas.

Activities in the production areas	Shed No	Mean ± sd LIA (μg/m^3)
Fabricating of metallic materials n=23	1	5.0 ± 0.31
	2	12.0 ± 1.86
	3	2.5 ± 0.07
	4	BDL
	7	2.28 ± 0.98
	8	BDL
	9	1.81 ± 0.42
	12	5.5 ± 0.84
	13	BDL
	15	BDL
	18	BDL
	19	BDL
	20	BDL
	21	1.64 ± 0.31
	22	1.45 ± 0.06
	23	BDL
	24	BDL
	25	BDL
	26	1.97 ±0.47
	28	BDL
	29	BDL
	30	BDL
	31	BDL
Grinding, heating, and soldering works (n=7)	17	3.37± 0.41
	32	BDL
	33	4.63 ± 0.55
	34	2.73 ± 0.27
	35	3.66 ± 0.30
	36	4.07 ± 1.60
	37	2.53 ± 1.45
Spray and brush painting (n=2)	6	53.61 ± 0.60
	16	56.42± 3.05
Welding areas (n=2)	11	126.85 ± 20.14
	27	117.36 ± 5.18
	Control areas	
	Library	BDL
	Open field	BDL

Key: BDL = below detection levels

N/A = Not applicable

sd =standard deviation

n = number of sheds,

From Table 4:3, airborne Pb levels in the 23 sheds ranged from of Below Detection Level (BDL) – 12.00 µg/m$^{3.}$ Workers in these sheds were engaged in fabrication of different scarp metals through folding to make diverse products such as boxes, chicken feeding trays, cooking pans and cake trays, metallic buckets. Shed 2 that was fabricating chicken feeding trays had the highest levels of airborne Lead of 12.00 µg/m^{3} compared to the other sheds that were fabricating different metallic materials. The large variation may be attributed to the fact that scrap metals from various sources of different alloys were used for fabrications of these products. Some of the scrap metals may have had high levels of Pb composition especially those that were used to fabricate chicken feeding trays released the highest levels of airborne Pb that was measured. Previous study by Street *et al*., (2020) on exposure to Pb and other toxic metals from informal foundries producing cookware from scrap metals showed varying BLL among workers. The distribution of Pb in blood ranged from 1.1 to 4.6 µg/dl with a median BLL of 2.1 µg/dl (IQR 1.7–2.5). This could be an important indication that diverse scrap metals may have varying Pb levels.

Seven sheds (n=7) where heating, grinding and soldering processes had mean airborne Lead levels of 3.00 ± 1.62 µg/m^{3} with a range of BDL- 5.00 µg/m^{3}. These operations involved heating metallic materials using charcoal to make them malleable so that they could twist or mold the objects into shapes like chisels as shown in Plate 4:1.

Plate 4.1: Open Heating of Scrap Metal to Make it Malleable

Source: author

Grinding was being done to either cut metals or to shine final products such as large cooking pans while soldering was done using solder wires to fuse different parts of materials to make products such as kerosene lamps. Previous studies done by Koh *et al*., (2015) showed that Pb fumes and dust are generated when activities such as grinding, sanding, cutting, or burnishing of metals containing Pb. Similar studies done by Mohammadyan, *et al*., (2019) reported Pb exposure among electronic soldering workers using Lead solders that resulted in sleep disorders.

The mean airborne Lead level was 55.0 ± 2.0µg/m^3 in Sheds 6 and 16, where painting was carried out using a brush and spray-gun. This process involved scrapping and removal of previously painted surfaces before application of new paint. Workers were also applying paint on the walls of the stalls and stores. These paints were stored in open drums that resulted in spillages as shown in Plate 4:2.

Plate 4.2: Paint Formulation and spraying Section.

Source: author

In addition, due to poor housekeeping in this area, spillage, chipped and scrapped paints were blown by wind back to air besides fumes from the sprayed paints. Studies done on 84 bridge painters showed painters in the New England were exposed to Pb during several job tasks that included sanding, scrapping and blasting (Rodrigues et al., 2009). These airborne Pb levels are comparable to the values reported by Were *et al.,* (2014), where the mean of 76.3 ± 33.2 µg/m^3 was obtained in the formal paint manufacturing company in Kenya. High airborne Pb values that were observed in this study could be attributed to high Pb in paint. Studies done in paint from the informal retail shops ranged from 221.0 ± 1.4 – 2688.4 ± 19.5 ppm against a specification of 90 ppm (Mwai *et al*., 2022). Paint manufacturers, for example, can add Lead compounds to enhance the brilliant color of paint; prevent corrosion, and enhance drying properties in oil-based paints. Lead-based paints when still in a can are not an immediate source of Lead. Nonetheless, the painted surfaces over time wear, and chip when disturbed thereby contaminating the environment including air that is inhaled leading to lead poisoning (Mwai *et al*., 2022). The International Conference on Chemical Management (ICCM) held in 2009, identified

Pb paint as an emerging human health and environmental policy issue. It was in this context that UNEP and WHO were tasked to provide leadership and form a partnership with diverse stakeholders to get rid of Lead paint and create a healthy and habitable environment (O'Connor, *et al.*, 2020). Kenya Bureau of Standard (KEBS) and the technical committee of the East Africa Standard for Paints and Allied Products have recently established 90 ppm as the allowable maximum total lead content in paints that should be sold in the East African market (Mwai *et al.*, 2022).

Overall, elevated levels of Pb in air were observed in the sections where welding works was common. For instance, shed 11 and 27 had the highest levels of airborne with a range of 117.36 ± 5.19 µg/m^3 and 126.84 ± 20.14 µg/m^3. Shed 11 had the highest Lead in air levels of 126.84 ± 20.14 µg/m^3 compared to all the sampled sites. These results are comparable with the mean value of 126.2 ± 33.2 µg/m^3 among scrap metal welders in a previous study done by Were *et al.*, (2014). Earlier studies carried out by Ashraph *et al.*, (2012) also reported elevated blood Lead levels (BLL) among informal sector workers especially the car radiator repairers, painters and welders. Studies done by Njoroge *et al.*, (2008) further revealed high BLL among informal sector workers in Ziwani N=55 with a mean BLL of 22.6 ± 13.4 µg/dl. Those found to have the highest BLL were welders (N=7) with a mean of 25.3± 17.8 µg/dl followed by painters'/ panel beaters with a mean of 24.1± 12.7 µg/dl.

Toxic substances that are found in smoke can affect the lungs, heart, kidneys, and the central nervous system. Fumes and gases emanating from welding can be harmful to health at high doses. Welders are exposed to heavy metals levels including Pb. When molten alloy is volatised, for example, small particles of 50-300 nm in diameter contained in fumes can reach in the alveolar region of the lungs thereby causing cardiovascular diseases (Zimmer & Maynard, 2002). During the study, the welding rooms and sections were cloudy when welding operations without local exhaust ventilated systems were taking place.

None of the welders in these sheds were using any respiratory protection devices against the fumes that prevailed. The welders were likely to have high BLL as observed in previous studies done by Were *et el*., (2014) where airborne Pb mean values of 126.2±39.9 ug/m^3 and BLL of 40.9 ±7.5 µg/dl were reported in workers, which exceeded the American Conference for Governmental Industrial Hygienists of Biological Indices for BLL of 30 µg/dl for a scrap welding plant (ACGIH, 2004). Research work done by Grashow *et al*., (2014) among construction workers showed those occupationally exposed to welding fume, had detectable Pb levels, manganese (Mn), cadmium (Cd), nickel (Ni) and arsenic (As) in toenail clippings of the workers.

The control area in this study was an open field and a library in Ongata Rongai Kajiado County twenty-two kilometers (22km) from the sampling site. The sites had airborne Pb levels BDL indicating these sites were free from airborne Pb contamination. These results could be attributed to lack of activities likely to emit airborne Pb. In the open field, there was no occupational activity within the area hence no likelihood airborne Lead within the area. The findings from the control area, compared to those of the fifteen Sheds, which represents 44.1% had airborne Lead levels BDL while 19 of the 34 Sheds (55.9%) had airborne Lead concentration ranging from 1.45± 0.06 µg/m^3 to 126.85 ± 20.14 µg/m^3 (Appendix I and II).

4.3 Compliance with the Regulatory Limits for Airborne Lead

Figure 4:3 presents the airborne Pb concentrations in relation to the US OSHA PEL for Pb in workplace air of 50 µg/m3 over an 8-hr TWA and the Kenya limit of 150 µg/m^3. Indicated by the horizontal lines in red for the US OSHA Standards of 50 µg/m^3 and in blue for Kenya Standards of 150µg/m^3 of Lead in air (LIA).

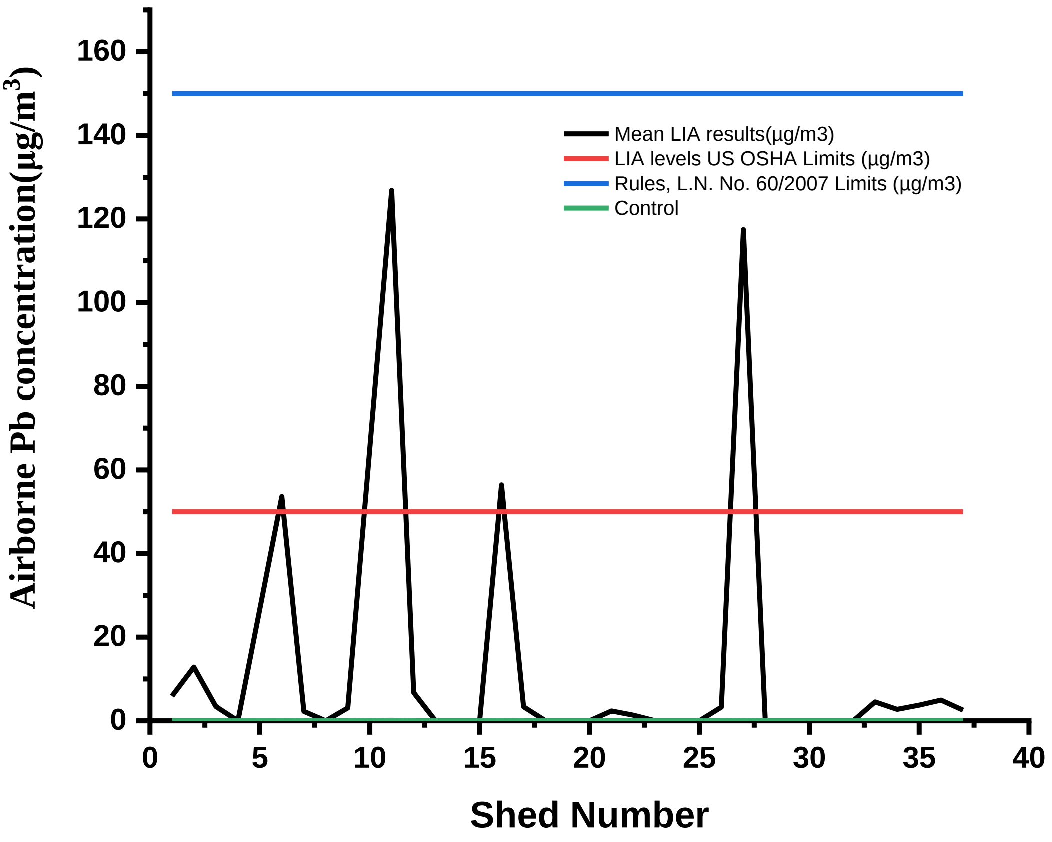


Figure 4.3: Graphical Presentation of Compliance Levels of Airborne Lead with the Regulatory Limits

The airborne Pb concentrations from the four sites that included Sheds 6, 11, 16 and 27 exceeded the PEL of 50 µg/m^3 set by the US OSHA. The PEL for Pb in workplace air for the general industry, was established to ensure that BLL do not exceed 60 µg/dl. Given that exposure to Pb levels that is lower than 50 µg/m^3 has been associated with diverse health outcome such as high blood pressure, decreased kidney function, reproductive effects and neurological impairment (National toxicology programme, 2012), there is therefore the need to review the airborne Pb levels to below 50 µg/m^3. For instance, from this study, most of the workers were engaged for more than 8 hours in the day and more than 5 days in a week hence the determined exposure Pb levels at 8-hr TWA is an underestimation for this sector of great importance especially when considering the childbearing women that were working in Shed 6 with a mean airborne Pb levels of 53.61 ± 0.60 µg/m$^{3.}$

The informal sector generally attracts different genders and age groups, it is necessary to have stringent regulatory framework to protect the different age groups from exposure to harmful levels. It should also be noted that apart from the female respondent who was working in Shed 6, there were other women doing various chores across the sheds. The activities included food preparation and selling of finished products. Furthermore, in Sheds 11, 16 and 27 where the mean airborne Pb levels were highest and above OSHA limits of 50 µg/m^3, female entrepreneurs were observed selling finished products and materials within the area, accompanied by their playing children under 6 years.

With reference to the Factories and Other Places of Work (Hazardous Substances) Rules, legal notice (L.N). No. 60 of 2007 the airborne Pb limit set at 150 µg/m^3 over an 8-hr TWA. However, none of the sampled sites had airborne Pb levels above the stipulated limit. This means that all the sites had acceptable levels of Lead in the work environment. Lead is however a well-studied metal that has been found to have significant public health problems and with no safe level of exposure (CDC, 2017). It is worth noting that workplace Pb may also affect children who can be exposed through Lead dust carried home in clothes and shoes of the parents (Shaffer and Gilbert, 2018). The National Toxicology Program (NTP, 2012) concluded that there is sufficient evidence for adverse health effects in children and adults at BLL of less than 5 µg/dl (CDC, 2012). Studies have further demonstrated that low Lead levels in adults can result in several adverse health outcomes therefore a number of federal agencies came up with recommended standards and enforceable regulations to control Pb levels in diverse media.

4.4 Occupational Safety and Health

4.4.1 Safety and Health Measures in the Workplace

This study sought to determine if there any safety and health measures practiced in the workplace in accordance to the OSH ACT, (2007) as shown in Figure 4:3

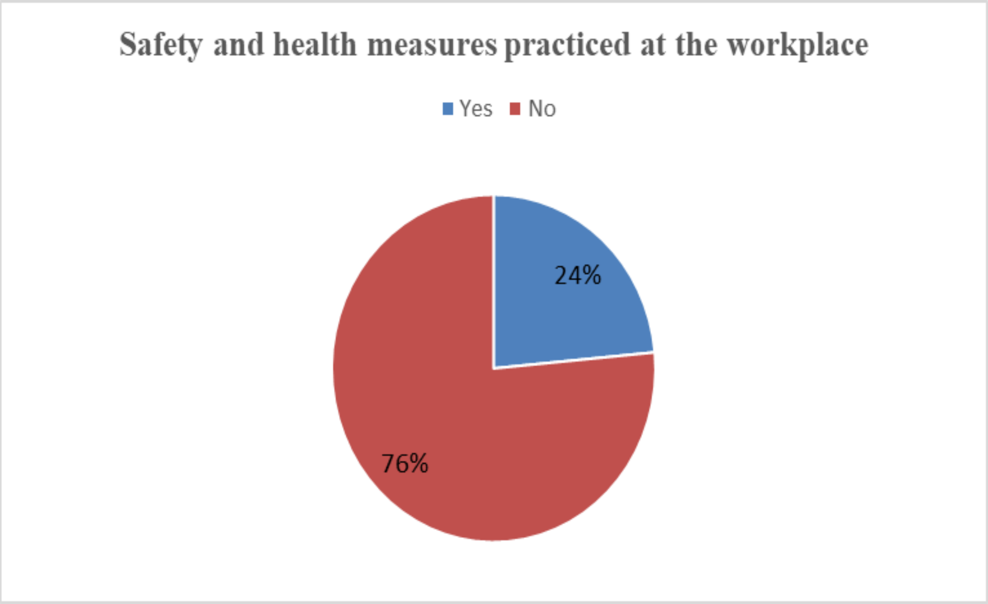


Figure 4.4: Safety and Health Measures Practiced at Work

Seventy six percent (76.0%) of the respondents agreed that there were no safety and health measures being practiced in the workplace. The data gathered through questionnaires, interviews and observations agree with observations made by Mamba (2006) that showed production areas lacked effective hazard control programmes. His study revealed working conditions among informal sector operators, were inadequate due to poor housekeeping, poor work practice and unsafe use of equipment, inadequate ventilation, lack of use of PPE, lack of appropriate sitting tools, storage of home clothes at work stations and poor lighting. This was also observed in Kamukunji "Jua Kali" sheds as shown in Plate 4:3.

Plate 4.3: Observations on Safety and Health Measures

Source: author

Those from sheds that had Lead in air (LIA) levels above OSHA US limits indicated there was no occupational safety and health measures practiced within their sheds except the respondent from shed 11. However, from observations made there was no occupational safety and health measures in place in shed 11.

4.4.2 Engineering Controls

Part 7 (e) of the Hazardous substance rules of 2007 requires where elimination or substitution is not possible, the occupier should use engineering controls to help reduce the risk from the hazard in the workplace. The study established that activities that are likely to generate airborne Pb the processes such as welding, heating, grinding and painting were done in the open without any engineering controls and was amid other processes such as fabrication as shown in Plate 4:2, 4:3 and 4:4.

According to Mamba (2006), welders suffer from lung problems such as bronchitis, asthma, emphysema and pneumonia. Other health problems include heart disease, skin disease, hearing loss and kidney damage. According to WHO (2017), adequate engineering controls should be put in place to effectively control emissions to air.

This requires isolation and enclosing those processes that are likely to generate and release airborne Pb and provide appropriate local exhaust ventilation (LEV).

4.4.3 Hygiene and welfare

Part X of the OSH ACT 2007 stipulates that every occupier to provide welfare provisions for the workers. This includes adequate supply of wholesome drinking water, suitable and adequate facilities for washing kept clean and orderly. The occupier should provide storage facilities for home clothes. Sitting/ rest facilities. This study evaluated accessibility to adequate sanitary facilities such as clean water, resting facilities, waste disposal services, and drainage systems among shed workers (Figure 4:5).

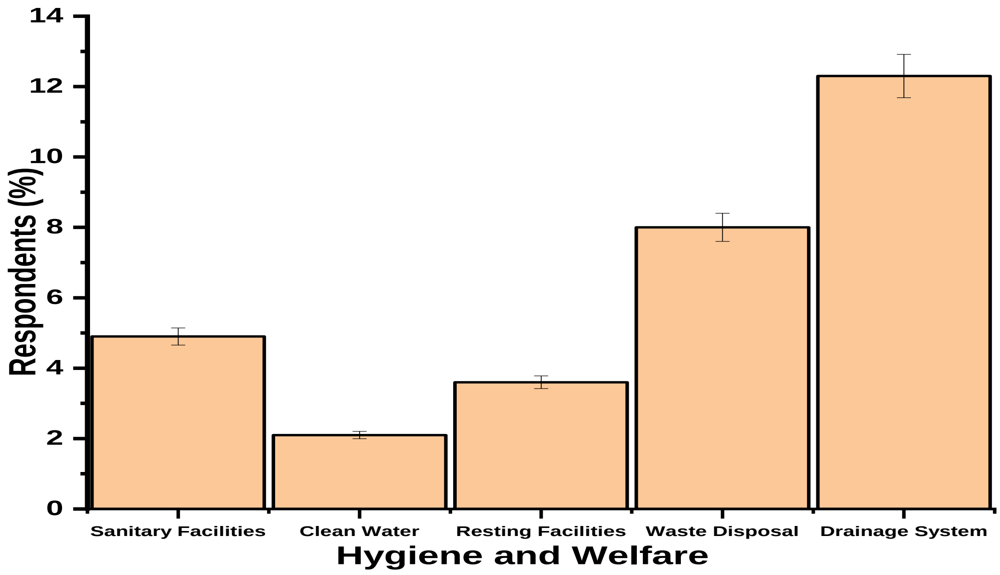


Figure 4.5: Accessibility to Adequate Hygiene and Welfare Services

From Figure 4:5, it can be observed that most of the respondents in this study didn't have adequate hygiene and welfare services. It was observed that only 4.9% of the respondents had access to sanitary facilities while 2.1% had access to a clean water supply. On the other hand, 3.6%, 8.0% and 12.3% of the respondents had access to resting facilities, waste disposal service and drainage systems respectively. The hygiene and welfare facilities in the area were also inadequate to cope with the risks that were identified. None of the workers had separate lockers to store working clothes and home cloths to minimize cross contamination as stipulated in section 6 (b) of the hazardous substance rules of 2007 as shown in plate 4:4, home clothes were stored in the work areas. Within the area there were no laundry facilities for cleaning work clothes which suggest that clothes are carried home, increasing risk of exposure in the family (Shaffer and Gilbert, 2018). There were no first aid facilities within the working area which is contrary to the requirement in section 82 (3) of the occupational safety and health ACT of Kenya 2007. The occupiers have not provided separate rooms for taking meals and resting places for the workers.

4.4.4 Provision of personal protective equipment (PPE)

This study evaluated accessibility of PPEs among informal Lead works and the results are given in Figure 4:6.

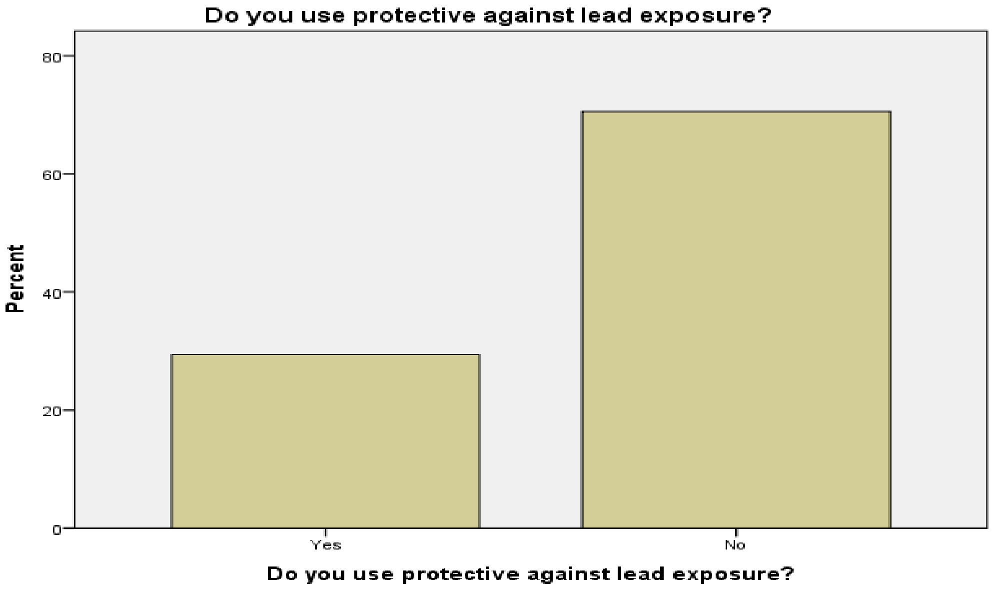


Figure 4.6: Use of PPEs among Workers

It was observed that 70.6% of the respondents stated that they did not use any protective measures against Pb exposure while only 29.4% used protective equipment. Only one respondent in shed 7 was observed to be using an improvised respiratory protection that was made from an old sweater as shown in Plate 4:4, but this does not offer adequate protection due to its low barrier properties.

Plate 4.4: Worker using a Sweater as a Respirator.

Source: author

In shed 6, 11, 16 and 27 where Pb in air levels were above the US OSHA PEL on an 8-hr TWA, none of the workers had any respirator for protection. According to Rodrigues *et al.,* (2008) and Santosa *et al., (2022).,* the use of PPEs such as gloves and respirators was associated with lower BLL. Failure of the workers to use PPEs could be attributed to lack of awareness and training about Pb exposure, lack of information on occupational safety and health and the lack of PPE. Although use of PPEs only protects the person wearing the equipment, the effectiveness of PPEs always relies on its proper usage. The PPEs must also be replaced when they no longer offer adequate protection. Guan *et al 2019* and Garrigou, *et al., 2020*. Section 101 (1) of the OSH Act 2007 requires every employer to provide and maintain appropriate PPE for their employees.

Section 8 (1) of the hazardous substance rules 2007, requires the occupier to provide suitable respiratory protective equipment and protective clothing to those exposed to air borne hazardous substances. The equipment should be able to control exposure to below limits. Information, instruction and supervision which is necessary with regard to the use of the equipment should be known to the employees. This could not be demonstrated as observed among the workers.

4.4.5 Knowledge on Lead Exposure

Figure 4:7 sought to find out the number of respondents who had information regarding Pb exposure and where they sourced that information.

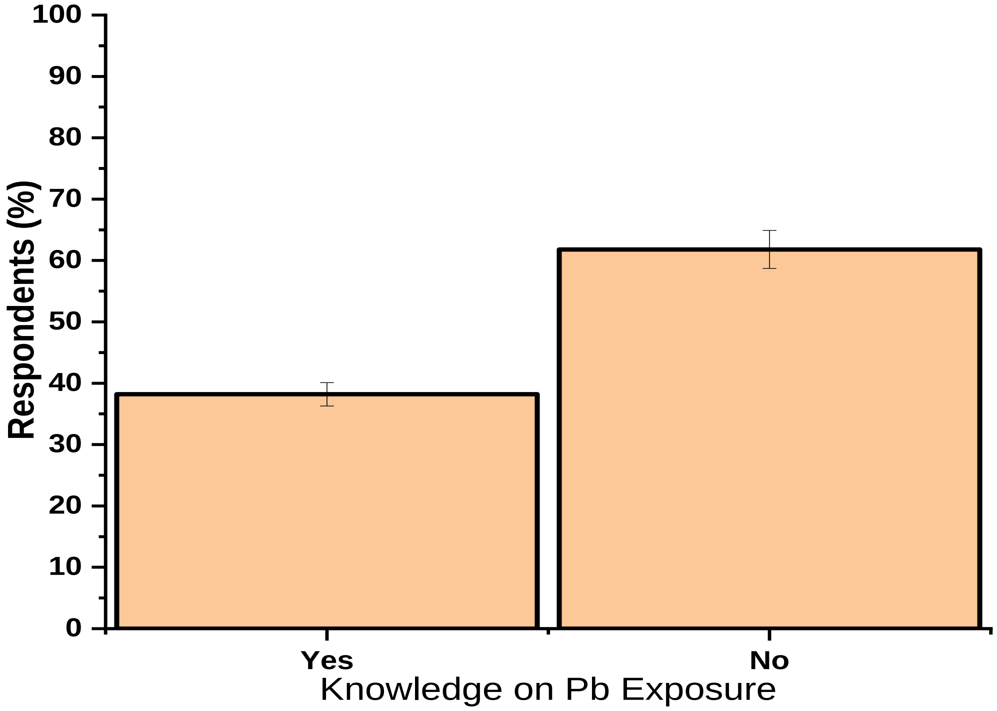


Figure 4.7: Knowledge about Lead Exposure

More than half (61.8%) of the respondents did not know about Pb exposure while 38.2 % had knowledge related to Lead exposure (Figure 4.8). However, these results are significantly higher than those reported by Ashraph *et al.* (2012) where only 6.72% were aware of Pb exposure. This indicates there is a general awareness to Lead exposure among the informal sector workers. However, to effectively control Lead exposure to the workers, shed Leaders should train all their staff on Lead, sources, exposure route and control measures WHO 2017. There were no material safety data sheets for paints used in the area neither other chemical in use

The study also sought to investigate the source of information on Pb exposure as presented in Figure 4:8.

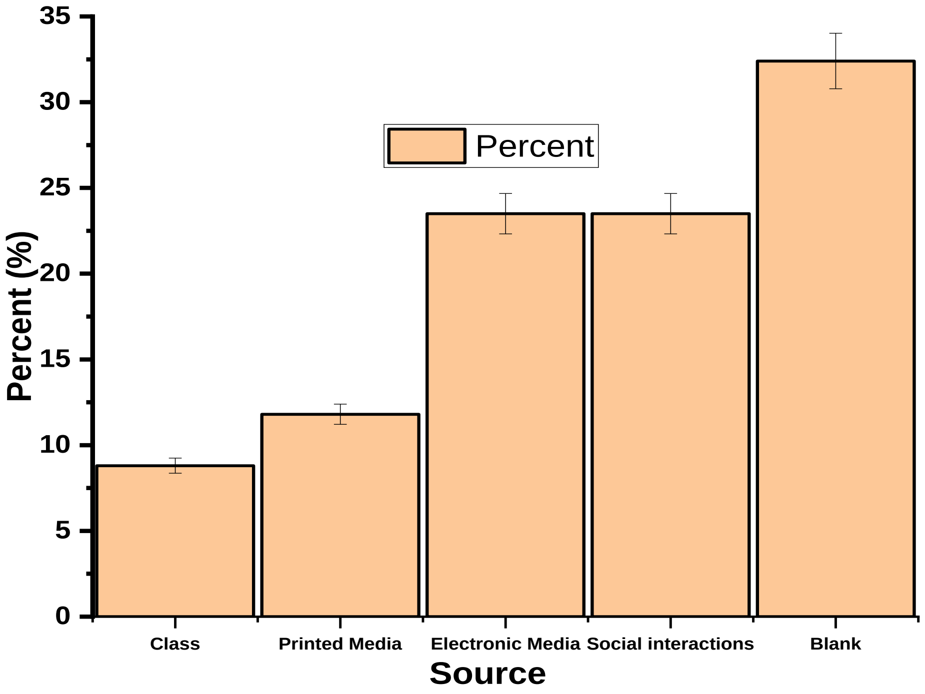


Figure 4.8: Respondents (%) against Lead Exposure

The results in Figure 4:8 suggested that only one (8.8%) shed Leader had no knowledge about Lead exposure and did not require further information. On the contrary, 44.1% lacked information and were willing to have awareness training programs on Lead exposure, on the hand, 26.5% had some knowledge on Lead exposure, while 20.6% clear understanding about Lead exposure in relation to health. Interestingly, the respondent who were working in shed 6 and 11 where the Lead concentration in air was above the OSHA PEL lacked information on Lead exposure, although they were willing to get the information. The respondent from shed 16 was very knowledgeable about Lead exposure from the print media while the one from shed 27 was knowledgeable and got this information from friends.

4.4.6 Duration of exposure

This study sought to find out the number of years the respondents have in this sector worked as it was directly related to exposure levels and the results are depicted in figure 4:9.

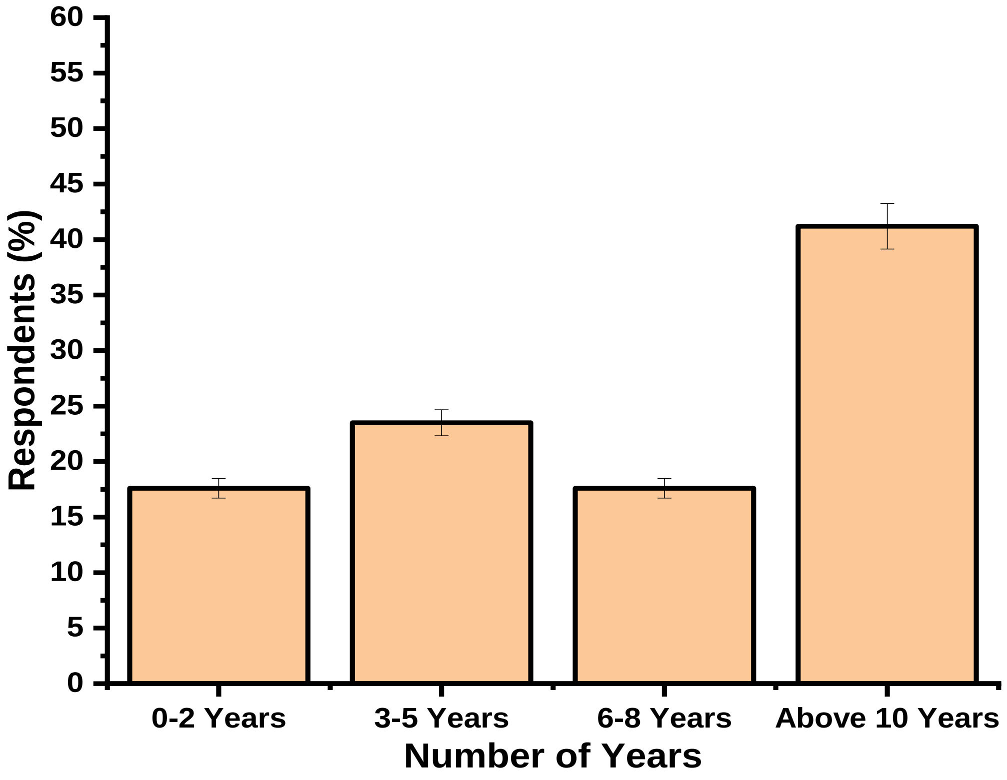


Figure 4.9: Duration of Exposure based on the Number of Years Worked

It can be observed that 41.2% of the respondents have worked for more than 10 years which includes those who responded from shed 27, 6 and 11 while the one from shed 16 had worked for 3-5 years. Studies done by Gennart *et al*., (1992) showed that a significant reduction in fertility among a group of 74 exposed workers with a mean exposure period of 10.7 years and BLL of 46.3µg/dl in comparison to a control group of 138 men with a mean BLL of 10.4µg/dl. The study concluded the duration of exposure to Lead is associated with decrease in fertility. Lin *et al*., (1996) also found a decline in male fertility rates on men exposed to Lead both environmentally or occupationally over a longer time. Work done by Rogers *et al*., (2014) has also shown that employees with long term exposure to Pb, leads to its deposition on the bone when air borne Lead concentrations are above 50µg/m^3.

4.4.7 Working hours in a day

The study sought to find out the number of working hours per day among the respondents and the results are depicted in Figure 4:10.

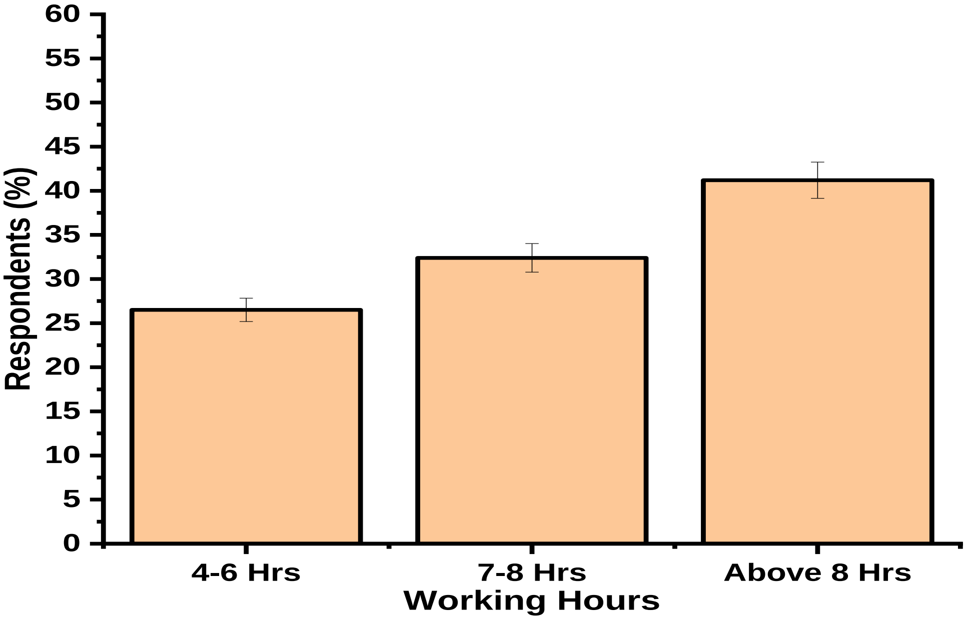


Figure 4.10: Number of working hours per day

It was observed that 70.0% of those who filled the questionnaires work for more than 10 hours in a day (Figure 4.10). The workers were reporting to work as early as 05.00 am and closed as late as 9:00 pm to ensure a smooth running of daily activities. Most of the work schedules run for six days in a week though only few workers operated for seven days a week without leave days. This response is like work done by Wekoye *et al*., (2019) who observed that 84.3% of the respondents worked for 9 hours per day with only 15.7% working for 8 hours per day with a mean number of hours being 8±1.86 hours per day. On the other hand, 88.1% of the respondents worked for 6 days and above per week with a mean working rate of 5±1.88 day per week. The respondents in shed 6 and 11 whose Lead exposure was above the OSHA PEL indicated that they worked for more than 8 hours per day. Those in shed 16 and 27 revealed that they worked for 7-8 hours in a day.

4.4.8 Health/Medical Surveillance

This study sought to evaluate if the respondents had noticed any changes to their health since starting to work in this sector (Figure 4:11).

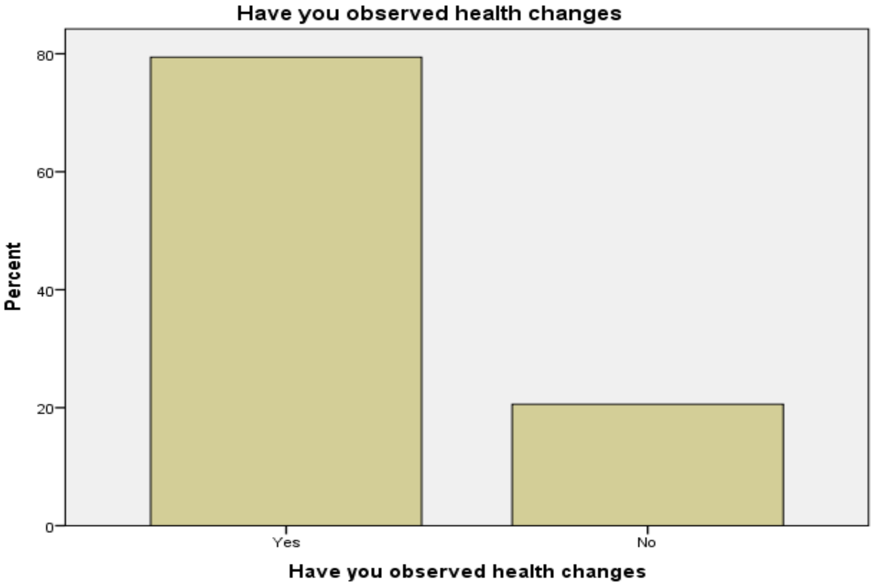


Figure 4.11: Respondents (%) against Medical Examinations

Although 79.4% of the respondents had noticed changes in health relating to their work environment, only 29.4% indicated they underwent medical examination including the one from shed 6 and 11 as shown in figure 4:12. From results, the small number of those who claimed to visit the hospital, most of them were unclear of how many times they seek medical care on ailments in a year, while those that visited the hospital did so once or twice a year. Low level of education and cost of medical care may have caused the low numbers who seek for the medical care services. According to Ashraph *et al.*, 2012, health care facilities are inadequate which may be a contributing factor to the small percentage of those who undergo medical examinations.

This study also sought to evaluate the frequency in which the respondents sought medical attention and the results are depicted in figure 4.12. Forty seven percent did not indicate the frequency, twelve percent of those who filled the questionnaires sought for medical care more than ten times.

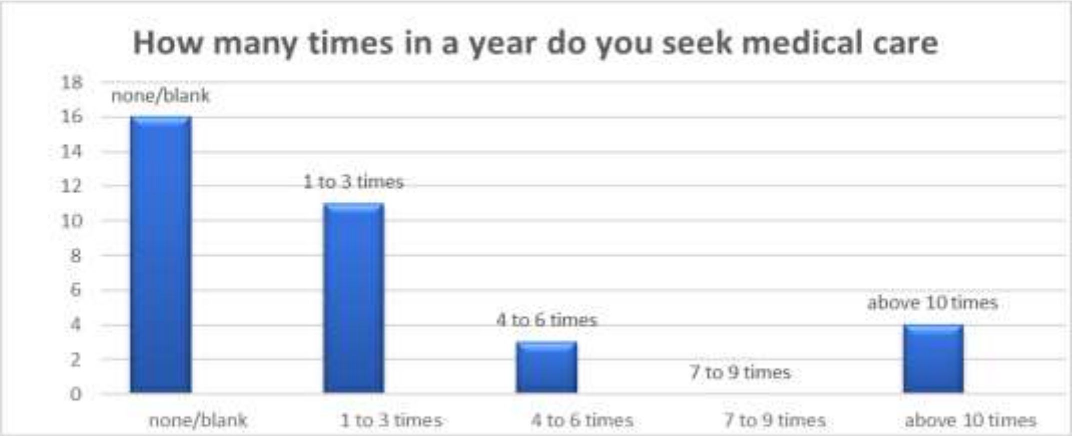


Figure 4.12: Respondents against Frequency of Seeking Medical Care

This study also sought to determine whether the visits to health facilities was as results of high blood pressure or chest and cough complications. The results of this question are (Figure 4.13)

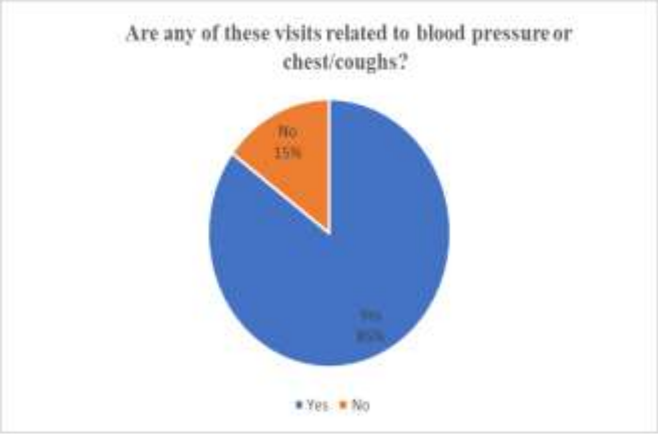


Figure 4.13: Visits Relating to Chest/Coughs or Blood Pressure.

All the respondents working in shed 6, 11, 16 and 27 indicated they had visited medical facilities due to chest/coughs or blood pressure. According to ASTDR 2007, Lead exposure causes small increases in blood pressure, particularly in middle-aged and older people; this may Lead to the workers in this area having high blood pressure.

Health and medical surveillance are not necessarily a means of protection against exposure to hazards but is more a monitoring tool to ensure the measures of protection are functioning adequately to prevent work-related illnesses. However, it can help in mitigating the risk.

4.4.9 Policies

Figure 4:14 depicts the perception of respondents about the need to formulate policies to curb hazards that result from Lead.

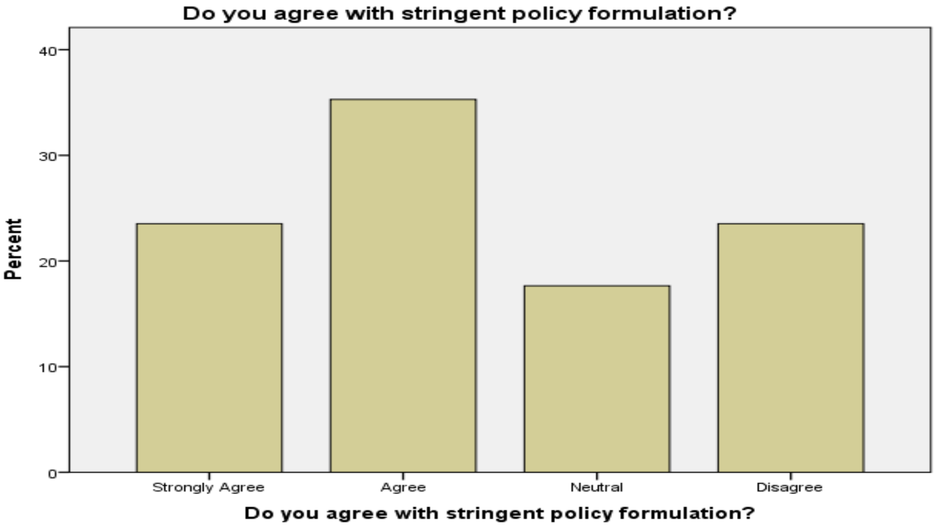


Figure 4.14: Reasons for Respondents not agreeing on Strict Measures to be Put in Place.

The need for such policies is justified by the fact that reports indicate adults such as those who participated in this study, there may be reproductive effects, such as decreased sperm count in men and spontaneous abortions in women (USEPA., 2002). In addition, there may be brain damage, kidney damage, and gastrointestinal diseases, while chronic exposure may cause adverse effects on the blood, central nervous system, blood pressure, kidneys, and vitamin D metabolism (USEPA., 2002;

Kaul *et al.,* 1999). The most alarming effect is that Lead is considered as a possible human carcinogen (IARC., 1987).

4.4.10 Correlation between Airborne Lead Levels and Empirical Survey

Table 4.4: Correlation coefficient matrix for airborne Lead Levels and Empirical survey questions

	Airborne Lead levels in the working areas	**Do you undergo medical examination**	**Type of PPEs you use**	**Do you agree with stringent policy formulation?**	**How much do you know about Lead exposure?**
Airborne Lead Levels in the Working Areas	1				
Do you undergo medical examination	0.069	1			
Type of PPEs you use	0.005	0. 717**	1		
Do you agree with stringent policy formulation?	-0.134	0.719**	O.601**	1	
How much do you know about Lead exposure?	-0.303	0.292	-0.045	0.274	1

**. Correlation is significant at the 0.01 level (2-tailed).

From Table 4:4, there is a positive correlation ($0 < r < 1$) between airborne Lead, PPE usage, medical examination, and negative correlation between ($0 > r < 1$) airborne Lead, policy, and knowledge on Lead exposure. There was also a positive correlation between use of PPEs, medical examination and positive correlation between stringent policy and use of PPEs. This observation implies that use of PPEs is highly dependent on the strategies and policies put in place in each shed as workers will tend to use the PPEs if strict policies are observed. Similarly, it can be observed from the correlation value that the use of PPEs also influences the frequency with which one visits a medical facility (Kothari, 2004).

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study evaluated airborne exposure to Lead among informal sector workers in Kamukunji "Jua Kali" Sheds in Kenya and provides baseline data of airborne Lead exposure levels. Based on the findings of the study, the following conclusions were drawn:

Nearly 60.0 % of the study area were polluted with Lead in the air (LIA) with the highest relative frequency between 0 – 14 µg/m^3. Most of the other activities are done in the open hence cross contamination of pollutants from various activities could have resulted in low lead in air values found within sheds where folding and fabrication of various metallic products was done.

In all the sampled sites, the LIA levels were within the levels set in the hazardous substance rules of 2007 of 150 µg/m^3. However, in comparison with the international laws, only four (11.7%) sheds that included 6, 11, 16 and 27 which had mean values of 53.61 ± 0.60, 126.84 ± 20.14, 56.42 ± 3.05 and 117.36 ± 5.19 µg/m^3, respectively exceeded 50 ug/m^3 permissive exposure limit of the US OSHA. Workers working in the four sheds with LIA levels above 50 µg/m^3 are likely to be exposed to lead since none of the workers within this section was using any respirator, the paint preparation area and the welding room did not have any local exhaust ventilation while at the incinerator the local exhaust ventilated mechanics was not appropriate.

There is no adequate safety and health measures put in place in at Kamukunji "Jua Kali" Sheds to protect workers from Lead in air exposure. During sampling, I observed that there was no evidence of cleaning of the workplace floor to remove any contaminated material from the workplace, poor housekeeping is a source of lead in air especially when wind blows within the sheds. Food preparation was being done within some of the sheds which may lead to contamination resulting to Lead exposure through ingestion. Workers were storing home clothes within the work stations that would result to contaminated clothes used after work while some were working in their home clothes. Use of home clothes or storage of home clothes in the work stations could result to spread of Lead exposure to family members. Cleaning of hands before taking meals was not observed. There was no provision of drinking water for the worker's, drinking water was provided by food vendors. The available washrooms were not adequate for the population and payment to use the available facilities could also hinder the workers from taking in a lot of drinking water for hydration.

Workers who spend more than 8 hours in the four sheds with high LIA levels (>50 $\mu g/m^3$) are more likely to experience adverse health effects related to Lead poisoning such as decreased sperm count in men and spontaneous abortions in women. In addition, there may be brain damage, kidney damage, and gastrointestinal diseases, while chronic exposure may cause adverse effects on the blood, central nervous system, blood pressure, kidneys, and vitamin D metabolism (USEPA., 2002; Kaul *et al.*, 1999, Ashraph *et al.*, 2012, WHO, 2010; Patrick, 2006; Landrigan, 1990).

Results from the questionnaires showed that more than half of workers in the informal sector are not informed on Pb exposure and associated health effects. They lack proper knowledge on Pb pollution as well as protective measures against exposure to Pb. Over 80% of the participants had experienced chest related complications which may largely be due to exposure to airborne Lead. It is also worth noting these workers were not confined to specific sheds. Movement of the workers from one shed to another was influenced by the activities within the shed. Ultimately each worker was exposed to diverse levels of Lead in air within the area.

5.2 Recommendations

The following recommendations are based on the results:

All the activities in shed 6, 11, 16 and 27 that were associated with high airborne Lead levels should be enclosed. For instance, the welding, painting and grinding working areas should be equipped with a combined ventilation and exhaust systems. Housekeeping of work areas should be improved and waste collected for disposal.

Employers should concrete the work surfaces to make cleaning easy. All working equipment’s should be kept free of dust accumulation. This will prevent any contaminated waste being blown into the air during movements and while working. Dry sweeping should also be discouraged in areas where Lead was detected.

Employers of workers in Sheds 6, 11, 16 and 27 should provide PPEs for their workers and this should include airborne Lead protection respirators, gloves and overcoats. Employers in this sector should also train the workers on correct use of PPE . For respirators, training on usage, fitting and leak test should be done. Male workers should also be trained on importance on clean shave to ensure a good fit of the respirators Bollinger, N. J., & Schutz, R. H. (1987).

All exposed workers should be provided with lockers for clean home clothes and the other for working clothes. Workers in these sheds should change to working clothes and other PPEs on arrival to the workplace. There is need to increase the number of washrooms and showers within the area. All exposed workers working within the production areas should be encouraged to shower and clean their PPE at the end of each shift to avoid carrying any contaminants to their homes. All contaminated clothes need to be handled carefully and washed in a laundry.

Designated smoking area within the location is necessary and smokers encouraged to use. Cigarette smoking should not be permitted in production areas. The occupiers should also identify a food and drinking rooms. Food preparation should not be done within shed 6, 11, 16 and 27 as observed in some since this may lead to food being contaminated with Pb. Workers should be encouraged to clean their hands before meals and use cutlery when taking meals.

All employees should have adequate training on occupational hazards and measures to take to lower any occupational risks associated with the work they undertake.

The occupiers of shed 6, 11, 16 and 27 should ensure all their employees undergo a pre-employment medical examination which should be carried out by authorized medical practitioners. These tests should include spirometry tests i.e., lung function tests for workers who are exposed to high levels of hazardous dust/ fumes like welders. They should also monitor the causes of sickness absence, by asking whether they or their doctor associate the illness with their work. Blood samples and urine samples (when and where required) must be taken at the pre-employment medical examination for measurement of blood Lead and other biological measurements. Biological monitoring of Lead exposure assesses exposure through inhalation, ingestion or skin absorption at any workplace where Lead or Lead compounds are produced, processed, packaged, used, handled, stored, transported or disposed.

Blood Lead monitoring should be done at least annually by an occupational medical practitioner. Registration of informal sector premises and annual safety audits should also be undertaken as required in the OSHA ACT of 2007. Sensitization on the importance of not having children in the workplace should be done to all the workers. The government should establish medical diagnostic center for heavy metals to facilitate monitoring of heavy metals in biological samples. The current education syllabus should incorporate safety and health issues from primary level to enhance awareness of safety and health requirements. The directorate of occupational safety and health should involve the informal sector in the world safety day campaigns to enhance safety in this sector.

5.2.1 Areas for Further Research

There is still room for further research on airborne Lead levels and blood Lead levels to workers elsewhere and mitigations measures to be established.

REFRENCES

Abdollahi, M., Sadeghi Mojarad A., & Jalali, N. (1996). Lead toxicity in employees of a paint factory, 10: 203–206: MJIRI.

Agency for Toxic Substances and Disease Registry (ATSDR) (1999). Public Health Service. Atlanta: U.S. Department of Health and Human Services. Toxicological Profile for Lead.

Agency for Toxic Substances and Disease Registry (ATSDR) (2007). Public Health Service. Atlanta: U.S. Department of Health and Human Services. Toxicological Profile for Lead.

Ajayi, O. M., & Odusanya, A. E. (2014). A Review Paper on Lead Exposure and Poisoning in Nigerian Children: The way forward. *Elixir International Journal of Pollution*, *70*, 23808-23811

Ashraph, J. J., Kinyua, R., Mugambi, F., & Kalebi, A. (2013). Health effects of Lead exposure among Jua Kali (informal sector) workers in Mombasa, Kenya: A case study of the "Express" Jua Kali workers. *International Journal of Medicine and Medical Sciences*, *5*(1), 24-29.

Azizi, M. H., & Azizi, F. (2010). Lead poisoning in the world and Iran.

Babayigit, A., Ethirajan, A., Muller, M., & Conings, B. (2016). Toxicity of organometal halide perovskite solar cells. *Nature materials*, *15*(3), 247.

Barsan, M. E., Boeniger, M. F., Crouch, K. G., Esswein, E. J., Kardous, C. A., Khan, A., ... & Willson, R. E. (2009). Preventing occupational exposures to Lead and noise at indoor firing ranges.

Beattie, A. D., Moore, M. R., & Goldberg, A. (1972). Tetraethyl-Lead poisoning. *The Lancet*, *300*(7766), 12-15.

Bellinger, D. C. (2005). Teratogen update: Lead and pregnancy. *Birth Defects Research Part A: Clinical and Molecular Teratology*, *73*(6), 409-420.

Bellinger, D. C., & Bellinger, A. M. (2006). Childhood Lead poisoning: the torturous path from science to policy. *Journal of Clinical Investigation*, *116*(4), 853.

Bollinger, N. J., & Schutz, R. H. (1987). *NIOSH Guide to industrial respiratory protection*. US Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Safety Research.

Cantarow A, Trumper M. (1944). Lead Poisoning. Baltimore, Md: Williams & Wilkins

CDC. What do parents need to know to protect their children? Retrieved from http://www.cdc.gov/nceh/Lead/ACCLPP/blood_Lead_levels.htm.

Centers for Disease Control and Prevention (CDC), (1997). Update: blood Lead levels--United States, 1991-1994. *MMWR. Morbidity and mortality weekly report*, *46*(7), 141

Centers for Disease Control and Prevention (CDC). (2005). Blood Lead levels--United States, 1999-2002. *MMWR. Morbidity and mortality weekly report*, *54*(20), 513.

Centers for Disease Control and Prevention. (2017). Tracking CRE. Centers for Disease Control and Prevention, Atlanta, GA. Retrieved from https://www. cdc.gov/hai/organisms/cre/trackingcre.html.

Charles, K. T. (2012, September). African Newsletter, on occupational health and safety Volume 22, number 2.

da Silva Ferrreira, A. P. S., Pereira, E. C., Salles, F. J., da Silva, F. F., Batista, B. L., Handakas, E., & Olympio, K. P. K. (2019). Home-based and informal work exposes the families to high levels of potentially toxic elements. *Chemosphere*, *218*, 319-327.

Dundar, B., Öktem, F., Arslan, M. K., Delibas, N., Baykal, B., Arslan, Ç., ... & Ilhan, I. E. (2006). The effect of long-term low-dose Lead exposure on thyroid function in adolescents. *Environmental research*, *101*(1), 140-145.

Elliott, P., Arnold, R., Barltrop, D., Thornton, I., House, I. M., & Henry, J. A. (1999). Clinical Lead poisoning in England: an analysis of routine sources of data. *Occupational and environmental medicine*, *56*(12), 820-824.

Ettinger, A. S., Leonard, M. L., & Mason, J. (2019). CDC's Lead poisoning prevention program: A long-standing responsibility and commitment to protect children from Lead exposure. *Journal of public health management and practice: JPHMP*, *25*(Suppl 1 LEAD POISONING PREVENTION), S5.

Garrigou, A., Laurent, C., Berthet, A., Colosio, C., Jas, N., Daubas-Letourneux, V., ... & Judon, N. (2020). Critical review of the role of PPE in the prevention of risks related to agricultural pesticide use. *Safety science*, *123*, 104527.

Gebrie, H. A., Tessema, D. A., & Ambelu, A. (2014). Elevated blood Lead levels among unskilled construction workers in Jimma, Ethiopia. *Journal of Occupational Medicine and Toxicology*, *9*(1), 12.

Gidlow, D. A. (2004). Lead toxicity. *Occupational Medicine*, *54*(2), 76-81.

GOK (2007). Occupational Safety and Health Act (OSHA) (2007), Nairobi: Government Printer.

GOK, (1999). The Environmental Management and Coordination Act (EMCA) (1999), Nairobi: Government Printer.

GOK, (2007). The Factories and Other Places of Work (Hazardous Substances) Rules, 2007, Nairobi: Government Printer.

GOK, (2014). The Environmental Management and Coordination (Air Quality) regulations (2014), Nairobi: Government Printer.

Gottesfeld, P., & Pokhrel, A. K. (2011). Review: Lead exposure in battery manufacturing and recycling in developing countries and among children in nearby communities. *Journal of occupational and environmental hygiene*, *8*(9), 520-532.

Grashow, R., Zhang, J., Fang, S. C., Weisskopf, M. G., Christiani, D. C., & Cavallari, J. M. (2014). Toenail metal concentration as a biomarker of occupational welding fume exposure. *Journal of occupational and environmental hygiene*, *11*(6), 397-405.

Guan, L. R., Xian, G. J., Rajendran, S. D., & Wahab, S. N. (2019). A study on the effectiveness of Personal Protective Equipment (PPE) on Building Construction Workers. In *E3S Web of Conferences* (Vol. 136, p. 04090). EDP Sciences.

Hsieh, N. H., Chung, S. H., Chen, S. C., Chen, W. Y., Cheng, Y. H., Lin, Y. J., ... & Liao, C. M. (2017). Anemia risk in relation to Lead exposure in Lead-related manufacturing. *BMC public health*, *17*(1), 1-12.

Hu, H., Shih, R., Rothenberg, S., & Schwartz, B. S. (2007). The epidemiology of Lead toxicity in adults: measuring dose and consideration of other methodologic issues. *Environmental health perspectives*, *115*(3), 455-462.

Hunter, D. (2006). The diseases of occupations. *Occupational Medicine*, *56*(8), 520-520.

International Agency for Research on Cancer (IARC). In IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. Vol. Volumes 1–42. Lyons, France: IARC; 1987. Overall Evaluation of Carcinogenicity: An updating of Monographs; p. 230-232.

Joint, F. A. O., & WHO Expert Committee on Food Additives. (1992). *Evaluation of certain food additives and contaminants: Forty-first report of the Joint FAO/WHO Expert Committee on Food Additives* (No. 837). World Health Organization.

Jolly R. (2006), “Hans Singer: The gentle giant”, Presented as a lecture in Geneva in the ILO on May 18th, 2006.

Kamukunji Jua Kali Association. (2006). Memberships register. Nairobi, Kamukunji Jua Kali Association

Karrari, P., Mehrpour, O., & Abdollahi, M. (2012). A systematic review on status of Lead pollution and toxicity in Iran; Guidance for preventive measures. *Daru*, *20*(1), 2.

Karrari, P., Mehrpour, O., & Abdollahi, M. (2012). A systematic review on status of Lead pollution and toxicity in Iran; Guidance for preventive measures. *Daru*, *20*(1), 2.

Kastury, F., Smith, E., Lombi, E., Donnelley, M. W., Cmielewski, P. L., Parsons, D. W., ... & Juhasz, A. L. (2019). Dynamics of Lead bioavailability and speciation in indoor dust and x-ray spectroscopic investigation of the link between ingestion and inhalation pathways. *Environmental science & technology*, *53*(19), 11486-11495.

Kaul B, Sandhu RS, Depratt C, Reyes F. (1999). Follow-up screening of Lead-poisoned children near an auto battery recycling plant, Haina, *Dominican Republic. Environ Health Perspect. 107*(11):917–920.

King, K. (1996). *Jua Kali Kenya: change & development in an informal economy, 1970-95*. Ohio State University Press.

Kinyanjui, N. (2008). The Kamukunji metalwork cluster in Kenya. *Knowledge, technology, and cluster-based growth, 2.*

Kinyua, A. N. (2014). Factors affecting the performance of small and medium enterprises in the Juakali sector in Nakuru Town, Kenya. *International Journal of business and management*, *16*(1), 53-62.

Koh, D. H., Locke, S. J., Chen, Y. C., Purdue, M. P., & Friesen, M. C. (2015). Lead exposure in US worksites: a literature review and development of an occupational Lead exposure database from the published literature. *American journal of industrial medicine*, *58*(6), 605-616.

Korda, M., & Mezić, I. (2018). Linear predictors for nonlinear dynamical systems: Koopman operator meet model predictive control. *Automatica*, *93,* 149-160.

Kordas K., Ravenscroft J., Cao V., and McLean, E. (2018). Lead Exposure in Low and Middle-Income Countries: Perspectives and Lessons on Patterns, Injustices, Economics, and Politics. *Int. J. Environ. Res. Public Health 2018*, *15*, 2351;

Kosnett, M. J. (2007). Heavy metal intoxication and chelators. *Basic and clinical pharmacology*. (10th ed.). *McGraw-Hill, New York*, 945-957.

Kothari, C. R. (2004). *Research methodology: Methods and techniques*. New Age International.

Kumar, R., (2007). Research Methodology: A Step-by-Step Guide for Beginners, (2nd.ed.), Singapore, Pearson Education.

Landrigan, P. J. (1990). Current issues in the epidemiology and toxicology of occupational exposure to Lead. *Environmental health perspectives*, *89,* 61.

Landrigan, P. J., & Todd, A. C. (1994). Lead poisoning. *Western Journal of Medicine*, *161*(2), 153.

Lanphear, B. P., Hornung, R., Ho, M., Howard, C. R., Eberly, S., & Knauf, K. (2002). Environmental Lead exposure during early childhood. *The Journal of pediatrics*, *140*(1), 40-47.

Lin, J. L., & Huang, P. T. (1994). Body Lead stores and urate excretion in men with chronic renal disease. *The Journal of rheumatology*, *21*(4), 705-709.

Lin, J. L., Yu, C. C., Lin-Tan, D. T., & Ho, H. H. (2001). Lead chelation therapy and urate excretion in patients with chronic renal diseases and gout. *Kidney international, 60*(1), 266-271.

Maina, E. G., Gachanja, A. N., Gatari, M. J., & Price, H. (2018). Demonstrating PM2.5and road-side dust pollution by heavy metals along Thika superhighway in Kenya, sub-Saharan Africa. *Environmental Monitoring and Assessment, 190*(4), 1–11

Mamba, R. M. (2006). *An assessment of occupational health and safety in the informal car maintenance, welding and spraypainting industry in Mbabane* (Doctoral dissertation).

Mañay, N., Cousillas, A. Z., Alvarez, C., & Heller, T. (2008). Lead contamination in Uruguay: the “La Teja” neighborhood case. In *Reviews of environmental contamination and toxicology* (pp. 93-115). Springer New York.

Mburu, C., Kinyua, R., & Muthusi, E. (2017). Effectiveness of ultraviolet light personal protective equipment used by informal sector arc welders in Machakos town, Kenya.

Mohammadyan, M., Moosazadeh, M., Borji, A., Khanjani, N., & Moghadam, S. R. (2019). Exposure to Lead and its effect on sleep quality and digestive problems in soldering workers. *Environmental monitoring and assessment, 191*(3), 184.

Mwai, L., Onyatta, J., & Were, F. H. Lead in Automotive Paints: A Potential Source of Exposure and Environmental Contamination. *Available at SSRN 4051266*.

Mwangi, J. N. (2016). Determinants in effective management of occupational health and safety measures in the Jua Kali sector in Nairobi County: A case of the metal workers in Kamukunji cluster. International Journal of Advanced Research in Management and Social Sciences, 5(11), 112-128.

Mwangi, J. N., Kadenyi, M. M., & Simel, S. (2016). Determinants in effective management of occupational health and safety measures in the jua kali sector in Nairobi county: a Case of the metal workers in Kamukunji cluster.

National Research Council. (2013). *Potential health risks to DoD firing-range personnel from recurrent Lead exposure*. National Academies Press.

Navas-Acien, A., Guallar, E., Silbergeld, E. K., & Rothenberg, S. J. (2007). Lead exposure and cardiovascular disease—a systematic review. *Environmental health perspectives*, *115*(3), 472-482.

Njoroge, G. K., Njagi, E. N., Orinda, G. O., Sekadde-Kigondu, C. B., & Kayima, J. K. (2008). Environmental and occupational exposure to Lead. *East African medical journal*, *85*(6), 284-291.

O’Connor, D., Hou, D., Ok, Y. S., & Lanphear, B. P. (2020). The effects of iniquitous lead exposure on health. *Nature Sustainability*, *3*(2), 77-79.

Occupational Safety and Health Administration (OSHA). Available from http://www.osha.gov/dts/sltc/methods/mdt/mdt1006/1006.pdf.

Odongo, A. O., Moturi, W. N., & Meshack, A. O. (2019). Risk of high blood Lead levels among informal sector automobile artisans: a case study of Nakuru town, Kenya. *International Journal of Environment and Health*, *9*(3), 258-270.

Olsen, O., & Kristensen, T. S. (1991). Impact of work environment on cardiovascular diseases in Denmark. *Journal of Epidemiology and Community Health*, *45*(1), 4-10.

Paoliello, M. M. B., & De Capitani, E. M. (2007). Occupational and environmental human Lead exposure in Brazil. *Environmental research*, *103*(2), 288-297.

Patrick, L. (2006). Lead toxicity, a review of the literature. Part 1: Exposure, evaluation, and treatment. *Alternative medicine review: a journal of clinical therapeutic*, *11*(1), 2-22.

Pogăcean, O. A., & Pop, C. (2015). Potential hand to mouth exposure to lead in a car battery factory. *Wulfenia Journal*, *22*, 83-90.

Robins, J. M., Cullen, M. R., Connors, B. B., & Kayne, R. D. (1983). Depressed thyroid indexes associated with occupational exposure to inorganic Lead. *Archives of internal medicine*, *143*(2), 220-224.

Rodrigues, A. L. S., Rocha, J. B. T., Mello, C. F., & Souza, D. O. (1996). Effect of Perinatal Lead Exposure on Rat Behaviour in Open‐Field and Two‐Wky Avoidance Tasks. *Pharmacology & toxicology*, *79*(3), 150-156.

Rodrigues, E. G., Virji, M. A., McClean, M. D., Weinberg, J., Woskie, S., & Pepper, L. D. (2009). Personal exposure, behavior, and work site conditions as determinants of blood Lead among bridge painters. *Journal of occupational and environmental hygiene*, *7*(2), 80-87.

Rubin, R., Strayer, D. S., & Rubin, E. (Eds.). (2008). *Rubin's pathology: clinicopathologic foundations of medicine*. Lippincott Williams & Wilkins.

Sandstead, H. H., Stant, E. G., Brill, A. B., Arias, L. I., & Terry, R. T. (1969). Lead intoxication and the thyroid. *Archives of internal medicine, 123*(6), 632-635.

Santosa, B., Rosidi, A., Anggraini, H., Latrobdiba, Z. M., Damayanti, F. N., & Nugroho, H. S. W. (2022). Mask Protection against Lead Exposure and Its Correlation with Erythropoiesis in Automotive Body Painters at Ligu District, Semarang, Indonesia. *Journal of Blood Medicine*, *13,* 113.

Sawanga, J. M. (2018). Health Effects of Noise Exposure among The'juakali'artisans: A Case Study of King'orani" Jua Kali" Artisans In Mvita Sub-County Mombasa Kenya (Doctoral Dissertation, Jkuat-Cohes).

Schwela, D. (2000). Air pollution and health in urban areas. *Reviews on environmental health*, *15*(1-2), 13-42.

Shaffer, R. M., & Gilbert, S. G. (2018). Reducing occupational Lead exposures: Strengthened standards for a healthy workforce. *Neurotoxicology*, *69*, 181-186.

Simiyu, S. W., & Cholo, W. (2016). Dynamics of occupational injuries among metal workers in Kamukunji Jua Kali Market, Nairobi, Kenya. *Dynamics*, *1*(12).

Steenland, K., & Boffetta, P. (2000). Lead and cancer in humans: where are we now? *American journal of industrial medicine*, *38*(3), 295-299.

Street, R. A., Goessler, W., Naidoo, S., Shezi, B., Cele, N., Rieger, J., ... & Mathee, A. (2020). Exposure to Lead and other toxic metals from informal foundries producing cookware from scrap metal. *Environmental research*, *191*, 109860.

Theuri, C. (2012). Small-scale enterprises and the informal sector in Kenya. *Afr Newslett*, *22*, 32-34.

Tong, S., Schirnding, Y. E. V., & Prapamontol, T. (2000). Environmental Lead exposure: a public health problem of global dimensions. *Bulletin of the World Health Organization*, *78*(9), 1068-1077.

U.S. EPA. (2002). Lead Compounds. Technology Transfer Network- Air Toxics Retrieved from http://www.epa.gov/cgi-bin/epaprintonly.cgi

Ulenbelt, P., Lumens, M. E., Géron, H. M., Herber, R. F., Broersen, S., & Zielhuis, R. L. (1990). Work hygienic behaviour as modifier of the Lead air-Lead blood relation. *International archives of occupational and environmental health*, *62*(3), 203-207.

US Department of Health and Human Services. (2007). Agency for Toxic Substances and Disease Registry: Toxicological profile for Lead. *US Department of Health and Human Services: Atlanta, GA, USA*.

Vigeh, M., Smith, D. R., & Hsu, P. C. (2011). How does Lead induce male infertility? *Iranian Journal of Reproductive Medicine*, *9*(1), 1.

Wekoye, S. A., Moturi, W. N., & Makindi, S. M. (2019). Occupational Safety and Health Hazards in the Informal Non-food Manufacturing Sector in Kampala City, Uganda. *Asian Journal of Medicine and Health*, 1-13.

Were F. H., Moturi C. M., Gottesfeld P., Wafula G. A., Kamau G. N., & Paul M. Shiundu, P. M. (2014). Lead Exposure and Blood Pressure among Workers in Diverse Industrial Plants in Kenya, *Journal of Occupational and Environmental Hygiene*, *11*(11), 706-715

Were, F. H., Kamau, G. N., Shiundu, P. M., Wafula, G. A., & Moturi, C. M. (2012). Air and blood Lead levels in Lead acid battery recycling and manufacturing plants in Kenya. *Journal of occupational and environmental hygiene*, *9*(5), 340-344.

Were, F. H., Moturi, M. C., Gottesfeld, P., Wafula, G. A., Kamau, G. N., & Shiundu, P. M. (2014). Lead exposure and blood pressure among workers in diverse industrial plants in Kenya. *Journal of occupational and environmental hygiene*, *11*(11), 706-715.

WHO (1987). Early Detection of Occupational Disease. Geneva, Switzerland: World Health Organization;

WHO (1995). *Lead. Environmental Health Criteria*, vol. 165. Geneva: World Health Organization.

WHO (2010). Childhood Lead Poisoning. Geneva, Switzerland: World Health Organization.

WHO (2015). Lead exposure in African children: contemporary sources and concerns.

Winkle, R. A., Mead, R. H., Ruder, M. A., Gaudiani, V. A., Smith, N. A., Buch, W. S., ... & Shipman, T. (1989). Long-term outcome with the automatic implantable cardioverter-defibrillator. *Journal of the American College of Cardiology*, *13*(6), 1353-1361.

World Health Organization. (2017). Recycling used Lead-acid batteries: health considerations.

Zeng, D. Z. (Ed.). (2008). Knowledge, technology, and cluster-based growth in Africa. World Bank Publications.

Zimmer, A. T. (2002). The influence of metallurgy on the formation of welding aerosols. *Journal of Environmental Monitoring*, *4*(5), 628-632.

APPENDICES

Appendix I: Mean Lead in Air Levels for Selected Sampling Sites.

shed no	LIA-8hrs-a (μg/m^3)	LIA-8hrs-b (μg/m^3)	LIA-8hrs-c (μg/m^3)	**Average** (μg/m^3)	**Std deviation** (μg/m^3)
1	5.6	6.2	3.2	5	0.31
2	11.6	15.0	9.4	12	1.856
3	1.1	5.1	1.2	2.47	0.07
4	BDL	BDL	BDL	BDL	-
6	53.3	54.3	53.24	53.61	0.60
7	1.2	3.12	2.53	2.28	0.98
8	BDL	BDL	BDL	BDL	-
9	2.3	1.15	2.00	1.82	0.024
11	150.0	117.2	113.34	126.85	20.14
12	6.2	6.3	4.0	5.5	0.84
13	BDL	BDL	BDL	BDL	-
15	BDL	BDL	BDL	BDL	-
16	56.9	0.0592	53.15	56.42	3.05
17	2.91	3.68	3.52	3.37	0.41
18	BDL	BDL	BDL	BDL	-
19	BDL	BDL	BDL	BDL	-
20	BDL	BDL	BDL	BDL	-
21	2.1	2.69	1.2	1.64	0.31
22	1.3	1.41	1.65	1.45	0.06
23	BDL	BDL	BDL	BDL	-
24	BDL	BDL	BDL	BDL	-
25	BDL	BDL	BDL	BDL	-
26	1.9	2.0	2.0	1.97	0.47
27	112.3	117.1	122.67	117.36	5.18
28	BDL	BDL	BDL	BDL	-
29	BDL	BDL	BDL	BDL	-
30	BDL	BDL	BDL	BDL	-
31	BDL	BDL	BDL	BDL	-
32	BDL	BDL	BDL	BDL	-
33	4.3	4.1	5.5	4.63	0.55
34	2.71	3.01	2.48	2.73	0.27
35	3.5	4.1	3.4	3.676	0.30
36	3.9	4.2	4.1	4.07	1.60
37	1.1	2.5	4.0	2.53	1.45
Control					
Library	BDL	BDL	BDL	BDL	-
Open field	BDL	BDL	BDL	BDL	-

Appendix II: Activities, number of workers and the Mean LIA results per sampling area

Shed No	Activities in the production areas	Number of workers (n)	Mean LIA results and STD (µg/m^3)
1	Fabricating chicken feeding trays	13	5.0 ± 0.31
2	Fabricating chicken feeding trays	13	12.0 ± 1.86
3	Fabricating cooking pots	16	2.5 ± 0.07
4	Fabrication of boxes and painting	14	BDL
7	Fabricating metallic boxes	16	2.28 ± 0.98
8	Fabricating ordinary Jikos	18	BDL
9	Fabricating pans	17	1.81 ± 0.24
12	Fabricating cooking pots	20	5.5 ± 0.84
13	Fabricating cooking pots	28	BDL
15	Fabrication of cake trays	28	BDL
18	Fabrication of boxes	16	BDL
19	Fabrication of boxes and chicken feeds trays	16	BDL
20	Fabrication of boxes and chicken feeds trays	18	BDL
21	Fabrication of boxes	15	1.64 ± 0.31
22	Fabricating metal boxes, painting	15	1.45 ± 0.06
23	Fabrication of Mopping buckets	12	BDL
24	Fabrication of barbeque Jikos	20	BDL
25	Fabrication of boxes	7	BDL
26	Fabrication of metal boxes	10	1.97 ±0.47
28	Fabricating deep frying jikos	20	BDL
29	Fabricating deep frying jikos	17	BDL
30	Fabricating deep frying jikos	20	BDL
31	Fabricating deep frying jikos	20	BDL
17	Grinding and Fabrication of boxes	13	3.37± 0.41
32	Heating and grinding	12	BDL
33	Grinding, heating and soldering work	12	4.63 ± 0.55
34	Grinding and fabricating jikos	25	2.73 ± 0.27
35	Grinding Boxes, Cake jikos, Food warmers	25	3.66 ± 0.30

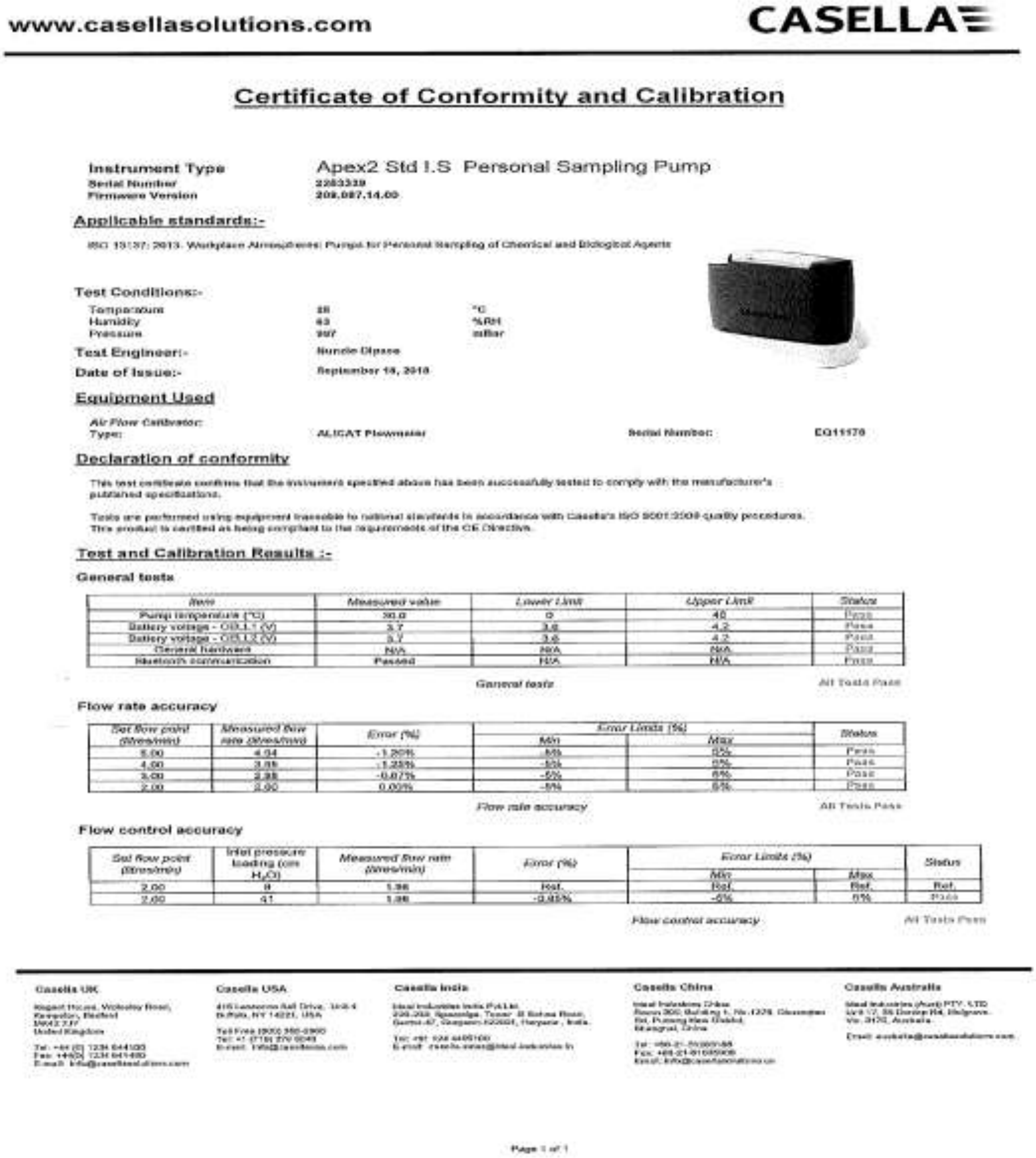
36	Grinding, heating and soldering work	17	4.07 ± 1.60
37	Grinding, heating and soldering work	20	2.53 ± 1.45
6	Painting metal boxes	10	53.61 ± 0.60
16	Spray Painting	13	56.42± 3.05
11	Welding	8	126.85 ± 20.14
27	Welding and fabrication of metal boxes	16	117.36 ± 5.18
Library	Private library	2	BDL
Open field	Children playground	N/A	BDL

Key – N- Shed number

n- number of workers

std – standard deviation

Appendix III: Calibration certificate A



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Certificate of Conformity and Calibration

Instrument Type Apex2 Std I.S Personal Sampling Pump

Serial Number 2283339

Firmware Version 209,087,14.00

Applicable standards:-

ISO 13137: 2013. Workplace Atmospheres: Pumps for Personal Sampling of Chemical and Biological Agents

Test Conditions:-

Temperature	25	°C
Humidity	63	%RH
Pressure	997	mBar

Test Engineer:- Nunzio Dipace

Date of Issue:- September 18, 2018

Equipment Used

Air Flow Calibrator:

Type: ALICAT Flowmeter Serial Number: EQ11178

Declaration of conformity

This test certificate confirms that the instrument specified above has been successfully tested to comply with the manufacturer's published specifications.

Tests are performed using equipment traceable to national standards in accordance with Casella's ISO 9001:2008 quality procedures. This product is certified as being compliant to the requirements of the CE Directive.

Test and Calibration Results :-

General tests

Item	*Measured value*	*Lower Limit*	*Upper Limit*	*Status*
Pump temperature (°C)	30.0	0	40	Pass
Battery voltage - CELL1 (V)	3.7	3.6	4.2	Pass
Battery voltage - CELL2 (V)	3.7	3.6	4.2	Pass
General hardware	N/A	N/A	N/A	Pass
Bluetooth communication	Passed	N/A	N/A	Pass

General tests All Tests Pass

Flow rate accuracy

Set flow point (litres/min)	*Measured flow rate (litres/min)*	*Error (%)*	*Error Limits (%)*		*Status*
			Min	*Max*	
5.00	4.94	-1.20%	-5%	5%	Pass
4.00	3.95	-1.25%	-5%	5%	Pass
3.00	2.98	-0.67%	-5%	5%	Pass
2.00	2.00	0.00%	-5%	5%	Pass

Flow rate accuracy All Tests Pass

Flow control accuracy

Set flow point (litres/min)	Inlet pressure loading (cm H_2O)	*Measured flow rate (litres/min)*	*Error (%)*	*Error Limits (%)*		*Status*
				Min	*Max*	
2.00	8	1.98	Ref.	Ref.	Ref.	Ref.
2.00	41	1.98	-0.85%	-5%	5%	Pass

Flow control accuracy All Tests Pass

Casella UK

Casella USA

Casella India

Casella China

Casella Australia

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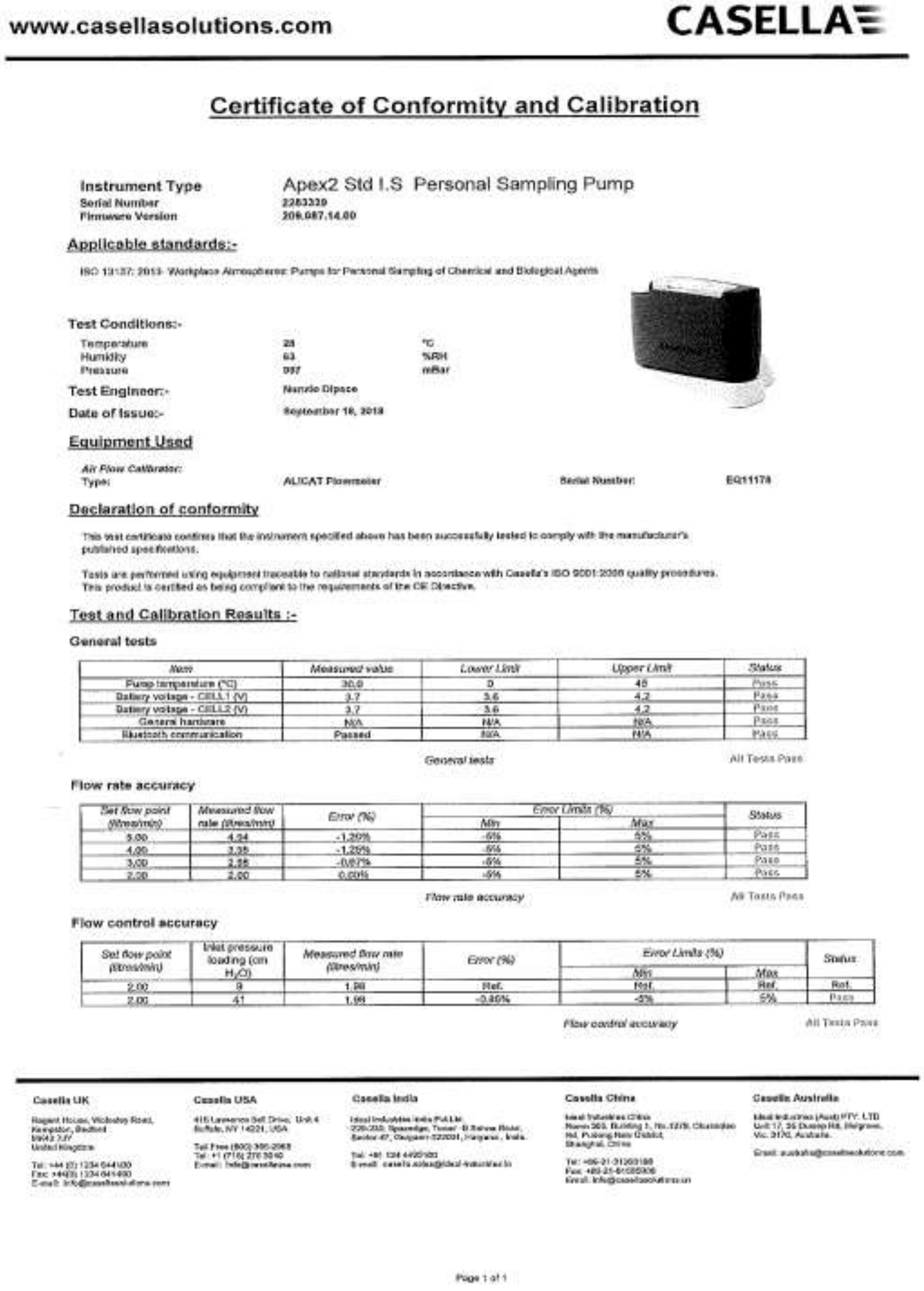
Appendix IV: Calibration certificate B



www.casellasolutions.com

CASELLA

Certificate of Conformity and Calibration

Instrument Type Apex2 Std I.S Personal Sampling Pump
Serial Number 2283329
Firmware Version 209.087.14.00

Applicable standards:-

ISO 13137: 2013- Workplace Atmospheres: Pumps for Personal Sampling of Chemical and Biological Agents

Test Conditions:-

Temperature	28	°C
Humidity	63	%RH
Pressure	997	mBar

Test Engineer:- Nunzio Dipace

Date of Issue:- September 18, 2018

Equipment Used

Air Flow Calibrator:
Type: ALICAT Flowmeter Serial Number: EQ11178

Declaration of conformity

This test certificate confirms that the instrument specified above has been successfully tested to comply with the manufacturer's published specifications.

Tests are performed using equipment traceable to national standards in accordance with Casella's ISO 9001:2008 quality procedures. This product is certified as being compliant to the requirements of the CE Directive.

Test and Calibration Results :-

General tests

Item	*Measured value*	*Lower Limit*	*Upper Limit*	*Status*
Pump temperature (°C)	30.0	0	45	Pass
Battery voltage - CELL1 (V)	3.7	3.6	4.2	Pass
Battery voltage - CELL2 (V)	3.7	3.6	4.2	Pass
General hardware	N/A	N/A	N/A	Pass
Bluetooth communication	Passed	N/A	N/A	Pass

General tests All Tests Pass

Flow rate accuracy

Set flow point (litres/min)	*Measured flow rate (litres/min)*	*Error (%)*	*Error Limits (%)*		*Status*
			Min	*Max*	
5.00	4.94	-1.20%	-5%	5%	Pass
4.00	3.95	-1.25%	-5%	5%	Pass
3.00	2.98	-0.67%	-5%	5%	Pass
2.00	2.00	0.00%	-5%	5%	Pass

Flow rate accuracy All Tests Pass

Flow control accuracy

Set flow point (litres/min)	Inlet pressure loading (cm H_2O)	*Measured flow rate (litres/min)*	*Error (%)*	*Error Limits (%)*		*Status*
				Min	*Max*	
2.00	9	1.98	Ref.	Ref.	Ref.	Ref.
2.00	41	1.96	-0.80%	-5%	5%	Pass

Flow control accuracy All Tests Pass

Casella UK **Casella USA** **Casella India** **Casella China** **Casella Australia**

Page 1 of 1

Appendix V: One sample t test

One-Sample Test

	Test Value = 0					
	t	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
USOSHA average	24806153884034828.000	33	.000	.05000	.0500	.0500
	2.329	33	.026	.0122758823 52941	.0015522893 85183	.0229994753 20699

	Test Value = 0					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
USOSHA_a average	2.48E+16	33	0	50	50	50
	2.329	33	26	12.2758824	1.55228939	22.9994753

Appendix VI: Cross tabulation

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
lia_8hrs_a * lia_8hrs_c	34	100.0%	0	0.0%	34	100.0%
lia_8hrs_a * lia_8hrs_b	34	100.0%	0	0.0%	34	100.0%

Appendix VII: Descriptive statistics

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
shed_no	34	1.0	37.0	19.824	10.8613
lia_8hrs_a	34	.00000	.15000	.0125065	.03310295
lia_8hrs_b	34	.00000	.11720	.0121812	.02979750
lia_8hrs_c	34	.00000	.12267	.0121400	.02963166
Avrg	34	.0000000000000000	.1268466666666667	.012275882352941	.030733981117418
osha_niosh_a	34	.05	.05	.0500	.00000
Std	34	.0000000000000000	.0201440446120767	.001260795936736	.003521769739637
Valid N (listwise)	34				

Appendix VIII: Correlations

Correlations

		level of awareness	avrg
level of awareness	Pearson Correlation	1	.112
	Sig. (2-tailed)		.602
	N	24	24
Avrg	Pearson Correlation	.112	1
	Sig. (2-tailed)	.602	
	N	24	34

Appendix IX: T-test

One-Sample Test

	Test Value = 0					
	t	Df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
level of awareness	10.153	23	.000	2.75000	2.1897	3.3103
Avrg	2.329	33	.026	.012275882352941	.001552289385183	.022999475320699

Appendix X: Correlations

Correlations						
		Airborne Lead Levels in The Working Areas	**Do you undergo medical examination**	**Type of protective you use**	**Do you agree with stringent policy formulation?**	**How Much Do You Know About Lead Exposure?**
Airborne Lead Levels In The Working Areas	Pearson Correlation	1	0.069	0.005	-0.134	-0.303
	Sig. (2-tailed)		0.702	0.978	0.459	0.086
	Sum of Squares and Cross-products	66.242	1.485	0.091	-6.879	-13.030
	Covariance	2.070	0.046	0.003	-0.215	-0.407
	N	33	33	33	33	33
Do you undergo medical examination	Pearson Correlation	0.069	1	.717**	.719**	0.292
	Sig. (2-tailed)	0.702		0	0	0.094
	Sum of Squares and Cross-products	1.485	7.059	4.235	12.118	4.118
	Covariance	0.046	0.214	0.128	0.367	0.125
	N	33	34	34	34	34
Type of protective you use	Pearson Correlation	0.005	.717**	1	.601**	-0.045
	Sig. (2-tailed)	0.978	0		0	0.801
	Sum of Squares and Cross-products	0.091	4.235	4.941	8.471	-0.529
	Covariance	0.003	0.128	0.15	0.257	-0.016
	N	33	34	34	34	34

Do you agree with stringent policy formulation?	Pearson Correlation	-0.134	.719	.601**	1	0.274
	Sig. (2-tailed)	0.459	0	0		0.117
	Sum of Squares and Cross-products	-6.879	12.118	8.471	40.235	9.235
	Covariance	-0.215	0.367	0.257	1.219	0.28
	N	33	34	34	34	34
How Much Do You Know About Lead Exposure?	Pearson Correlation	-0.303	0.292	-0.045	0.274	1
	Sig. (2-tailed)	0.086	0.094	0.801	0.117	
	Sum of Squares and Cross-products	-13.030	4.118	-0.529	9.235	28.235
	Covariance	-0.407	0.125	-0.016	0.28	0.856
	N	33	34	34	34	34
**. Correlation is significant at the 0.01 level (2-tailed).						

Appendix XI: Model summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.648[a]	.420	.258	1.240	.420	2.588	7	25	.037

a. Predictors: (Constant), Have you heard about Lead exposure? How Much Do You Know About Lead Exposure? Have you observed health changes, Occupational safety you know of being practiced at work? Do you agree with stringent policy formulation? Do you undergo medical examination, Where did you learn about Source of Knowledge on Lead Exposure.

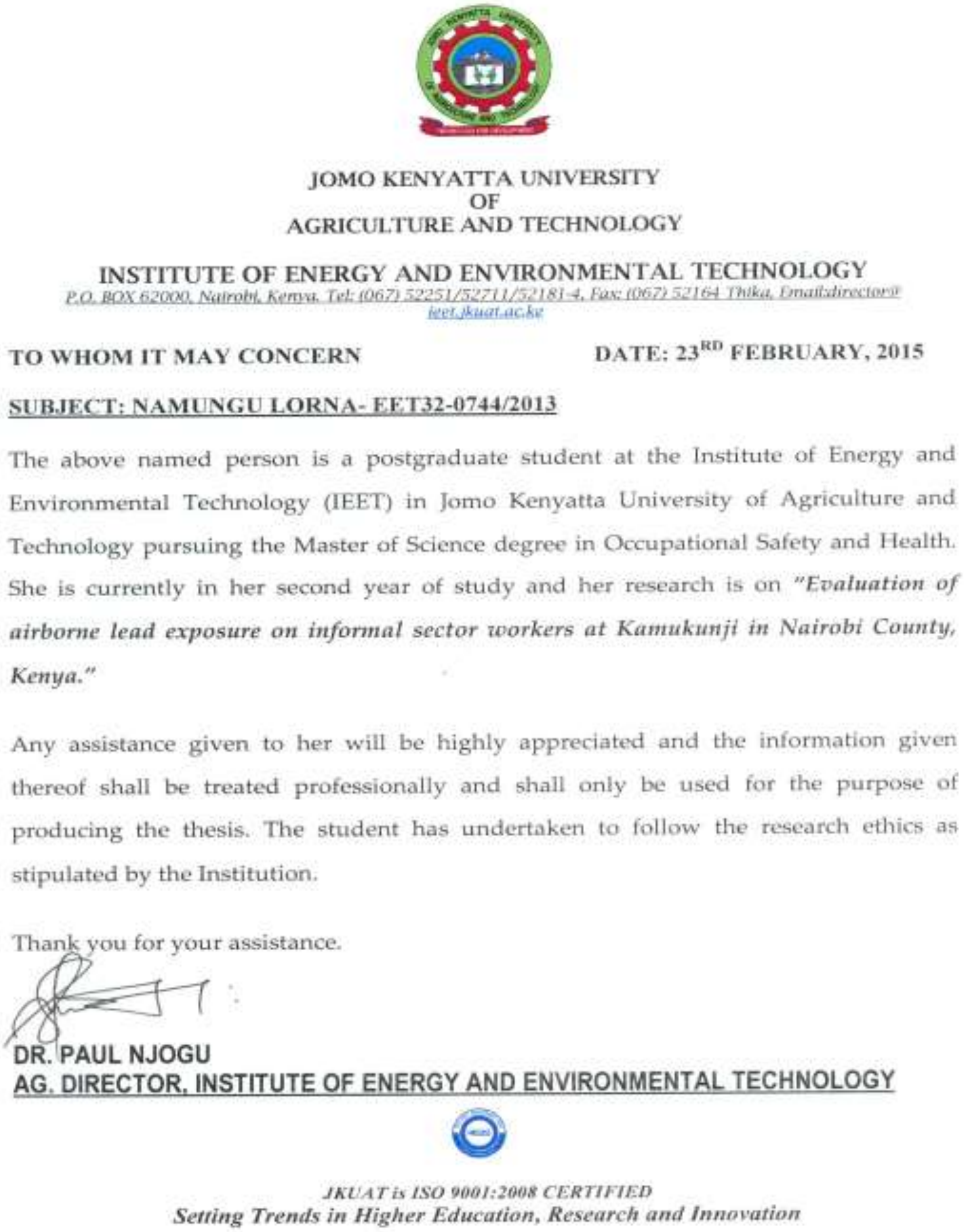
b. Dependent Variable: Airborne Lead Levels in The Working Areas

Appendix XII: Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	5.393	1.356		3.977	.001			
	Occupational safety you know of being practised at work?	-2.804	.901	-.881	-3.110	.005	-.210	-.528	-.474
	Have you observed health changes	-.529	.752	-.153	-.704	.488	-.049	-.139	-.107
	Do you undergo medical examination	.184	.949	.060	.193	.848	.069	.039	.029
	Do you agree with stringent policy formulation?	-.516	.360	-.401	-1.434	.164	-.134	-.276	-.218
	How Much Do You Know About Lead Exposure?	-.589	.266	-.382	-2.220	.036	-.303	-.406	-.338
	Where did you learn about Source of Knowledge on Lead Exposure.	.956	.462	.864	2.067	.049	.062	.382	.315
	Have you heard about Lead exposure?	1.183	1.005	.408	1.178	.250	.001	.229	.179

a. Dependent Variable: Airborne Lead Levels In The Working Areas

Appendix XIII: Permit from Jomo Kenyatta University of Agriculture and Technology



JOMO KENYATTA UNIVERSITY
OF
AGRICULTURE AND TECHNOLOGY

INSTITUTE OF ENERGY AND ENVIRONMENTAL TECHNOLOGY
P.O. BOX 62000, Nairobi, Kenya. Tel: (067) 52251/52711/52181-4, Fax: (067) 52164 Thika, Email:director@
ieet.jkuat.ac.ke

TO WHOM IT MAY CONCERN **DATE: 23RD FEBRUARY, 2015**

SUBJECT: NAMUNGU LORNA- EET32-0744/2013

The above named person is a postgraduate student at the Institute of Energy and Environmental Technology (IEET) in Jomo Kenyatta University of Agriculture and Technology pursuing the Master of Science degree in Occupational Safety and Health. She is currently in her second year of study and her research is on ***"Evaluation of airborne lead exposure on informal sector workers at Kamukunji in Nairobi County, Kenya."***

Any assistance given to her will be highly appreciated and the information given thereof shall be treated professionally and shall only be used for the purpose of producing the thesis. The student has undertaken to follow the research ethics as stipulated by the Institution.

Thank you for your assistance.

DR. PAUL NJOGU
AG. DIRECTOR, INSTITUTE OF ENERGY AND ENVIRONMENTAL TECHNOLOGY

JKUAT is ISO 9001:2008 CERTIFIED
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Appendix XIV: Kamukunji permit

RECEIPT

KAMUKUNJI JUA KALI ASSOCIATION

P.O. Box 78558-00507, Cellphone 0724 559217, 0721 252186, 0733 558402
Email: kamujuakali@yahoo.com

No. 198

Date 27/8/2015

Received from LORNA NAMUNGU KITUI

the sum of shillings Paid Three Thousands

Being payment of:-
(i) MONTHLY CONTRIBUTION ☐
(ii) TITLE DEED ☐
(iii) OTHER PURPOSE (SPECIFY) ✓
(iv) ANNUAL LAND RATES ☐

Deadline of payment

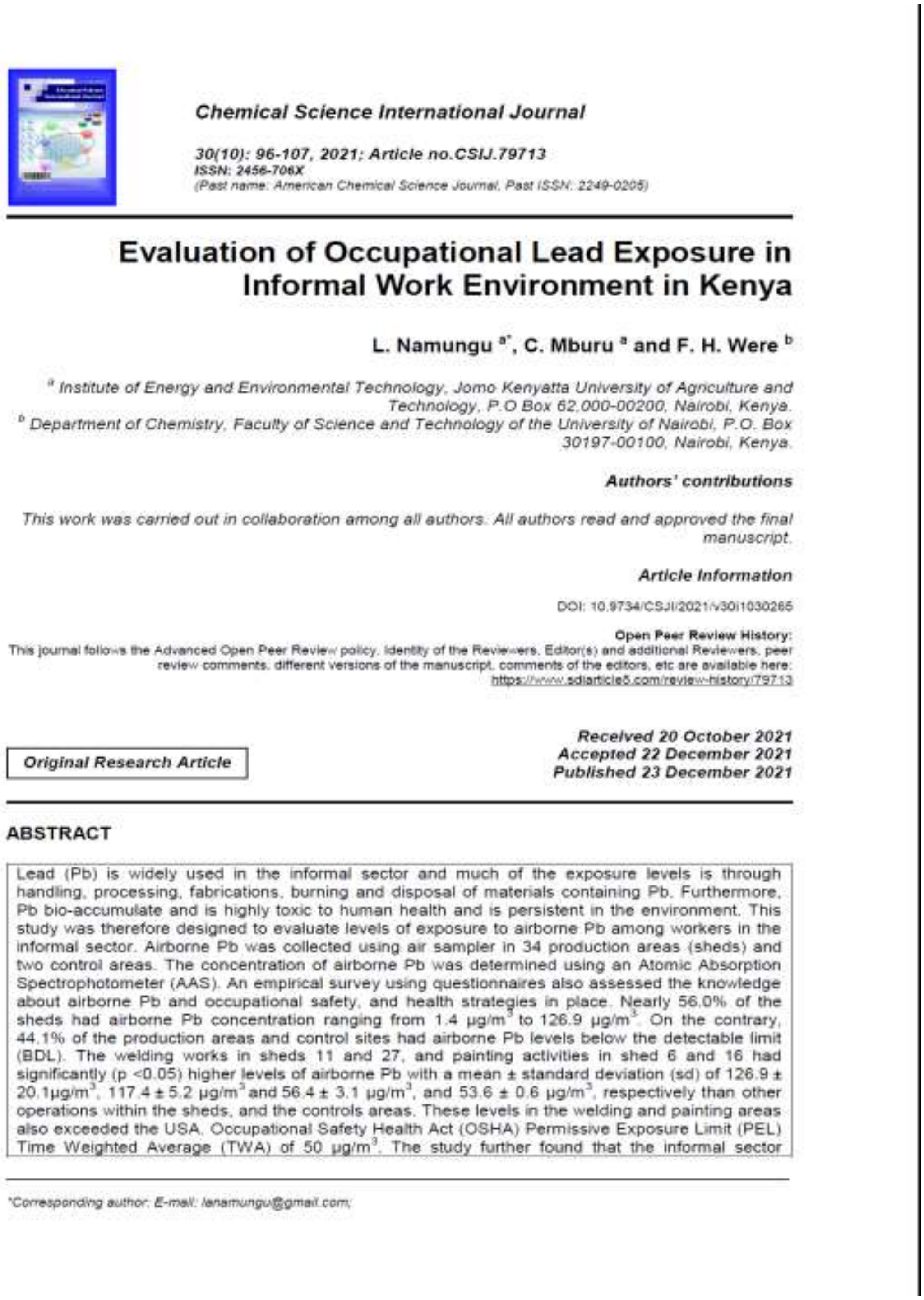
KSHS 3000/=

Cash/Cheque

With Thanks

Signature
for Kamukunji Jua Kali Association

Appendix XV: Published Journal Paper



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Evaluation of Occupational Lead Exposure in Informal Work Environment in Kenya

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[b] Department of Chemistry, Faculty of Science and Technology of the University of Nairobi, P.O. Box 30197-00100, Nairobi, Kenya.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Lead (Pb) is widely used in the informal sector and much of the exposure levels is through handling, processing, fabrications, burning and disposal of materials containing Pb. Furthermore, Pb bio-accumulate and is highly toxic to human health and is persistent in the environment. This study was therefore designed to evaluate levels of exposure to airborne Pb among workers in the informal sector. Airborne Pb was collected using air sampler in 34 production areas (sheds) and two control areas. The concentration of airborne Pb was determined using an Atomic Absorption Spectrophotometer (AAS). An empirical survey using questionnaires also assessed the knowledge about airborne Pb and occupational safety, and health strategies in place. Nearly 56.0% of the sheds had airborne Pb concentration ranging from 1.4 $\mu g/m^3$ to 126.9 $\mu g/m^3$. On the contrary, 44.1% of the production areas and control sites had airborne Pb levels below the detectable limit (BDL). The welding works in sheds 11 and 27, and painting activities in shed 6 and 16 had significantly ($p < 0.05$) higher levels of airborne Pb with a mean ± standard deviation (sd) of 126.9 ± 20.1$\mu g/m^3$, 117.4 ± 5.2 $\mu g/m^3$ and 56.4 ± 3.1 $\mu g/m^3$, and 53.6 ± 0.6 $\mu g/m^3$, respectively than other operations within the sheds, and the controls areas. These levels in the welding and painting areas also exceeded the USA. Occupational Safety Health Act (OSHA) Permissive Exposure Limit (PEL) Time Weighted Average (TWA) of 50 $\mu g/m^3$. The study further found that the informal sector

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