KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

KUMASI, GHANA

COLLEGE OF HEALTH SCIENCES

SCHOOL OF PUBLIC HEALTH

DEPARTMENT OF OCCUPATIONAL AND ENVIRONMENTAL HEALTH AND SAFETY

PARTICULATE MATTER EXPOSURE AMONG ARTISANS AT SUAME-MAGAZINE IN KUMASI METROPOLIS, GHANA

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A THESIS SUBMITTED TO THE DEPARTMENT OF OCCUPATIONAL AND ENVIRONMENTAL HEALTH AND SAFETY, SCHOOL OF GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCIENCE IN OCCUPATIONAL AND ENVIRONMENTAL HEALTH AND SAFETY.

BY

ANABEL ADUTWUMWAA BONSU

(PG 5234518)

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DECLARATION

I hereby declare that this submission is my own work towards this MSc and that, to the best of my knowledge, it contains no material previously published by another person, nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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Certified by:

Dr. Sam Kofi Newton ………………………………. ………………………….

(Supervisor) Signature Date

Certified by

Dr. Sam Kofi Newton ……………………………….. ………………………

(Head of Department) Signature Date

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Health and Safety. I would also like to appreciate all lecturers of the school of public health. May God richly bless you all.

To the woman who made this goal achievable. The strongest woman I know. The one who held me down through it all. My mother, Mrs. Martha Kyerewaa Bonsu. Mummy I love you so much and I appreciate everything you did and continue to do for us. God is not done with you just yet. Finally, my love and appreciation goes to my sister Sheila Serwaa-Bonsu, my niece Adepa Kyerewaa Obeng-Darko and my brother Yaw Mensah-Bonsu Jnr for their love and support.

DEDICATION

This work is dedicated to my sweet father the late Mr. Yaw Soadwa Mensah-Bonsu, may his soul rest in eternal peace. Daddy this is for you. I miss you and I love you.

ABSTRACT

Air pollution is one of the major causes of mortality and disease globally. This study was conducted on particulate matter exposure among artisans at Suame-Magazine. Sampling was carried out at three different spots within Zone 21 of Suame-Magazine for a period of 8 hours per sampling section. The same process was done at a residential area which was the control. PM_{10} particles were collected using the HAZ-DUST EPAM 7500 air sampling device. Questionnaires were administered to assess the health effects on artisans as a result of exposure to PM_{10}. A Human Health Risk Analysis was calculated to predict the health risk posed on an artisan as a result of PM_{10} inhalation. A number of hazards artisans are faced with were identified. PM_{10} concentrations from the exposed group and the control group was 211µg/m^3 and 103 µg/m^3 respectively. The level of PM_{10} pollution was very high in the exposed group compared to the control group. PM_{10} pollution level was very high in both groups with mean concentrations exceeding WHO and Ghana EPA guideline values, 50 µg/m^3 and 70 µg/m^{3}respectively. Results from a Chi-square analysis revealed that there was an association between exposure to PM_{10} particle pollution and some health outcomes like hypertension, breathing difficulties, headaches and asthma. Results from the Human Risk Analysis revealed that the risk of exposure to particulate matter inhalation to an artisan was moderate. Hazards identified were slips, trips and falls, cuts, burns, punctures, noise and eye irritations. Air pollution has been proven to be a threat to the health of humanity and the environment as a whole. Proper safety precautions should be taken by workers at all times and more research should be carried out in this particular area due to the due to the fact that it is major health threat to humans, animals and the environment as a whole.

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LIST OF ABREVIATIONS AND ACRONYMS

CHRPE: Committee on Human Research Publication and Ethics

CV: Cardiovascular

EPA: Environmental Protection Agency

FADD: Field Average Daily Dose

HHRA: Human Health Risk Analysis

HQ: Hazard Quotient

IARC: International Agency for Research on Cancer

PAH: Poly aromatic Hydrocarbons

PM: Particulate Matter

PPE: Personal Protective Equipment

RQ: Risk Quotient

SADD: Safe Average Daily Dose

USEPA: United States Environmental Protection Agency

VOCs: Volatile Organic Compounds

WHO: World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of Study

When we think of air, the first thing that comes to mind is oxygen which is very essential for life. But air is not made of only oxygen. Air actually is composed of several gases or it is a mixture of gases. It is not a single unit like it is seen. Air consists of nitrogen (N2-78.084%), oxygen (O2 20.947%), carbon(IV) dioxide (CO2-0.033%), Argon (Ar-0.934%), water vapor and other gases in minute quantities (Sandhyarani, 2019). Access to clean air is very essential and important as our health depends on it but that is not the case always because of air pollution and its accompanying effects. Air pollution can be broken down into two types; outdoor or ambient air polluting and indoor or household air pollution. There are natural sources and anthropogenic sources of air pollution. Some natural sources are volcanic activities, sea salt spray, dust blown by the wind and soot. Anthropogenic sources are agriculture, burning of biomass, industrial activities, vehicle emissions and mining activities. These two sources of air pollution release harmful substances and chemicals into the atmosphere that are detrimental to health. (Apte, Brauer, Cohen, Ezzati, & Pope, 2018). Outdoor air pollution) is one of the major causes of mortality and morbidity across the world. Approximately 4.2 million sudden deaths worldwide are connected to outdoor air pollution, mainly from heart disease, lung cancer, stroke and respiratory infections in children. Pollutants that have serious health effects and are a concern to public health include particulate matter (PM), ozone (O_3), nitrogen dioxide (NO_2) and Sulphur dioxide (SO_2) (WHO, 2018b).

Particulate matter (PM) maybe be defined as a substance made up of liquids and very minute particles. (Anderson, Thundiyil, & Stolbach, 2012). Exposure to particulate matter can harm both your lungs and your heart. Some health effects linked to particulate matter exposure are premature death in vulnerable people who have heart or lung disease, difficulty in breathing, irregular heartbeat, asthma, irritation of the eyes, throat and nose and coughs. Those that are most vulnerable to be affected are people with lung disease, children and adults (US EPA, 2018). PM_{10} are known as the coarse particles and $PM_{2.5}$ is known as the fine particle because it can get deep into your lungs.

Suame magazine is one of the major industrial areas in Ghana. It is made up of about 200,000 workers in the areas of manufacturing industries, metal fabrications, auto body works, fitting shops and scraps (Frimpong, 2009). There are different sectors that come together to form the Suame cluster. These sectors are grouped into manufacturing, auto body works, metal fabrication, sale of engineering materials and accessories, sale of vehicle spare-parts and food vendors (Obeng, 2015)

In simple terms, an artisan is someone who works with his or her hands. An artisan is someone that works with their hands in making things, installing things, repairing things and maintaining things with the help of tools, equipment or machinery.

1.2 PROBLEM STATEMENT

Air pollution is known to be a major cause of health problems globally. According to the World Health Organization, global outdoor air pollution accounts for 29% of all mortality and morbidity from lung cancer, 17% from acute lower respiratory infection, 24% from stroke, 25% from ischemic heart disease and 43% from chronic obstructive pulmonary disease (WHO, 2018). Activities of these artisans unfortunately contribute to the pollution of air. Particulate matter is produced and introduced into the ambient air and some are inhaled easily by the workers because they do not have appropriate personal protective equipment such as nose masks to protect them. Particulate matter can penetrate deep into lung passageways and the bloodstream leading to cardiovascular, cerebrovascular and respiratory effects.

In 2013, it was named as a cause of lung cancer by WHO's International Agency for Research on Cancer (IARC). It is also the most widely used source of assessment of health effects from outdoor air pollution exposure (WHO, 2018b). These local artisans mostly work in small shops and are self-taught so they do not know the basic safety procedures to follow. They also do not wear the appropriate Personal Protective Equipment (PPE) to protect them from harm. Most of them cannot even afford these PPEs so they are forced work in their own attires. Due to these reasons they are exposed to the harmful effects of particulate matter which affect their health eventually.

1.3 JUSTIFICATION

Suame-Magazine is one of the most industrialized places in Ghana with huge number of industrial activities being conducted. These activities contribute greatly to particulate air pollution. Constant and regular air monitoring is needed to be done so as to check the levels of air pollution and to make sure that air quality standards are being met. Results from monitoring the air can help in assessing health risk among workers as well as other people in the community by informing policy, monitoring and implementation regulatory bodies such as the Environmental Protection Agency (EPA).

Lots of studies have been done in the different countries across the world on the assessment of particulate matter but not much has been done in Ghana. This study therefore seeks to add to literature and serve as a point of reference to policy makers, academicians as well as anyone with an interest in the same research area. Upon some inquiries made by talking to some of the artisans, a lot of researchers have been to this study site to conduct different studies at the area but none was there to check the air quality and to assess for particulate matter. This new discovery therefore makes this study more important and needed.

1.4 CONCEPTUAL FRAMEWORK

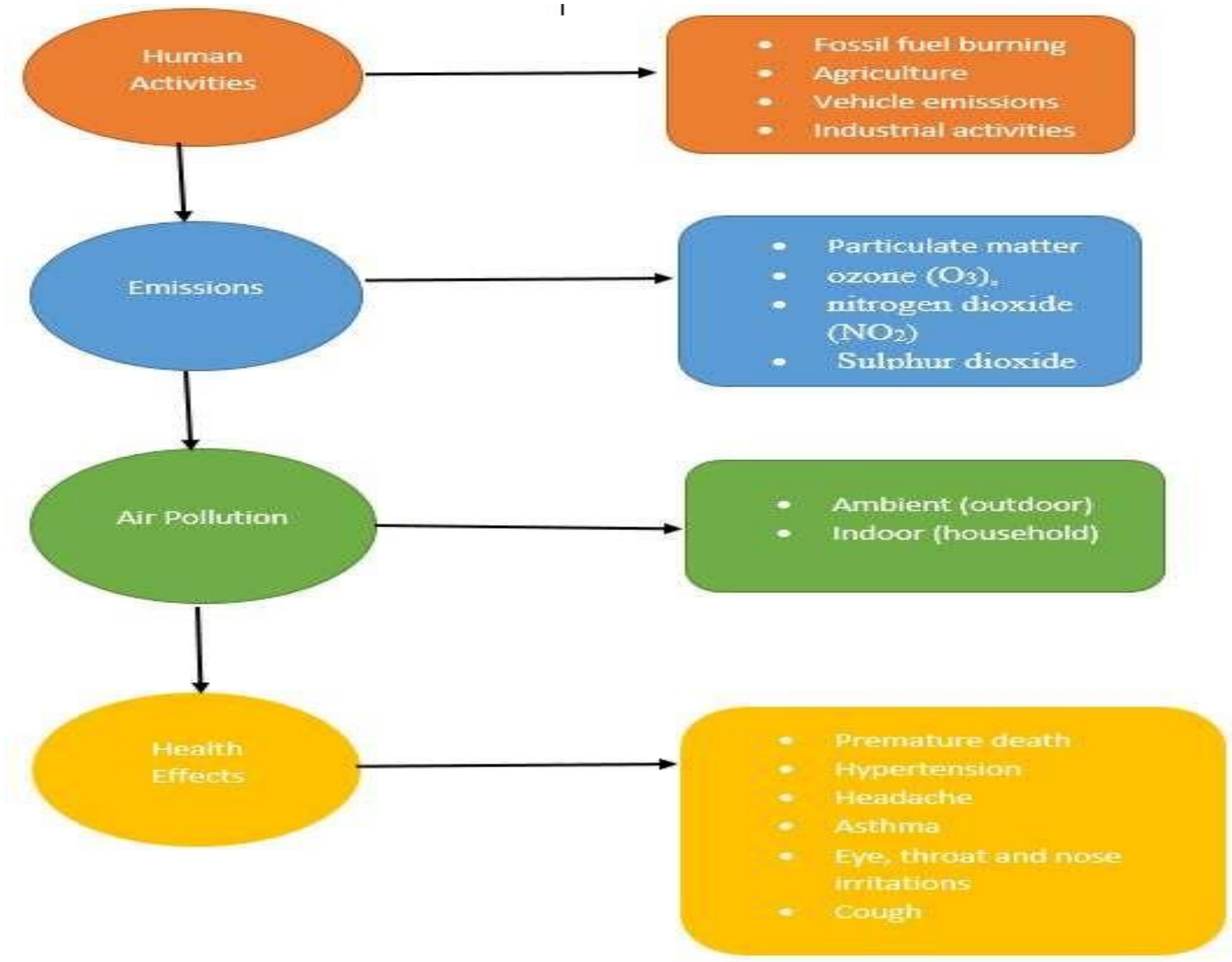

Figure 1.1 Conceptual framework of the particulate matter exposure and its resulting health effects.

This framework gives an overall overview of the health impacts of particulate air pollution. Human activities such as agriculture, burning of fossil fuel, vehicle emissions, mining and industrial activities release into the atmosphere harmful substances such as particulate matter, carbon monoxide and Sulphur dioxide. These pollutants pollute the air and cause series of health effects such as lung and heart diseases, breathing difficulties, asthma, eyes, throat and nose irritations, hypertension and premature death.

1.5 Research Questions

1. What are the levels of particulate matter in the ambient air at Suame-Magazine and the control?
2. What are the associations between short-term exposure to particulate matter and its resulting health effects?
3. What are the possible occupational hazards artisans are faced with at the workplace?

1.6 AIMS AND OBJECTIVES

1.6.1 Aim

The aim of the study was to assess the level of particulate matter exposure to artisans at SuameMagazine, Kumasi.

1.6.2 Specific Objectives

- To measure the level of particulate matter in the ambient air around artisans at Suame-Magazine.
- To assess the association between particulate matter exposure and its resulting health effect among artisans at Suame-Magazine.
- To identify possible occupational hazards associated with activities of the artisans at Suame-Magazine.

CHAPTER TWO

1.0 LITERATURE REVIEW

2.1 Air Quality

The earth's atmosphere consists of a mixture of gases and particulate-phase substances. Nitrogen (N_2) and Oxygen (O_2) are the most abundant occupying 75% and 21% respectively, with the remaining 1% occupied by trace gases. There are some gases whose concentrations are constant: N_2, O_2, Argon (Ar), Neon (Ne), Helium (He), Krypton (Kr), Hydrogen (H_2) and Xenon (Xe), and there are other gases that vary in concentrations temporally and spatially: water vapor (H_2O), Carbon dioxide (CO_2), Carbon monoxide (CO), Methane (CH_4) O_3, the Nitrous oxides, Ammonia (NH_3), Formaldehyde (HCHO), Sulphur dioxide (SO_2), etc. (Kingdom, 2008).

Human beings have the fundamental human right to have access to free air and water of the utmost quality or in the least, acceptable. Air quality in simple terms is how good or how bad the air in our surroundings is and also a necessary need for the survival of humans, plants, animals and natural resources. Good air quality means air that is clean, clear and does not contain harmful contaminants such as smoke, dust, smog and other gaseous pollutants. Poor air quality is air that has been polluted by emissions from both natural and anthropogenic sources. Poor air quality can affect the health of humans, plants and animals. Therefore, the health of humans and the environment is threatened when air pollution reaches high concentrations (Rinkesh, 2019).

2.2 Air Pollution

Air pollution may be defined as the presence of substances in air at levels, time and prevalence that negatively affect human and animal health and also the environment ("Air Polution and Health in Rapidly Developing Countries," 2001). Air pollution is the price the world has to pay for industrialization, high demand for conveniences and comfort and better quality of life. But air pollution is not a new concept. There is a lot of evidence in history that proves that air pollution has been present for hundreds of years. An example is soot found on the ceilings of caves back in the Stone Age. This is evident that there are high levels of pollution associated with poor ventilation from open fires. The cavemen lit fires in their caves to probably keep warm and to prepare their meals ("Air Polution and Health in Rapidly Developing Countries," 2001).

Core bits of glaciers in Greenland showed a rise in pollution linked with Greek, Roman, and Chinese metal production. According to Brimblecombe (1987) as cited by Gordon and Murray (2001), the remains of early humans indicated that they suffered the damaging effects of smoke in their homes. Mummified lung tissues were often observed to be dark. This was probably due to long exposure to particulate air pollution in the smoky dwellings of ancient humans ("Air Polution and Health in Rapidly Developing Countries," 2001)

According to Anderson (2000) as cited by Geiger et al (2010), the industrial revolution hundred years ago triggered the monitoring and regulation of air pollution. The emergence of clean air legislation both nationally and internationally was prompted due to some major air pollution events that happened between the 1930's and the 1950's. December 1930, Belgium, a thermal reversal trapped fog over a 15-mile-distance of high-walled Meuse Valley that contained farms, villages, steel mills and chemical plants. This left people living in the valley with nausea, shortness of breath, stinging eyes and burning throats. 60 people died with thousands more ill in just 3 days. The cause of death and illness was over thirty different chemical pollutants trapped under the thick fog and death rate was increased ten times above normal (Geiger, Cooper, & Cooper, 2010).

Another significant and well-known occurrence that affected London, England in December 1952 and known to be the worst air pollution event in the history of the United Kingdom, and the most important in research and a source of awareness creation to the general public on the link between air quality and health was “The Great Smog of '52”. Air pollutants from coal were collected during a cold weather and formed a thick layer of smog that lasted for 5 days (Friday to Tuesday, 9 December, 1952). It went away after the weather changed. It was not considered an important event at that time although it caused poor visibility and even penetrated the indoor areas. This was because London had witnessed many smog occurrences in the past. However, after some weeks, medical reports revealed that 4,000 had died preterm and 100,000 more got sick as a result of the effects of the smog on the human respiratory tract (Geiger et al., 2010).

2.3 Ambient (outdoor) Air Pollution

The quality of both outdoor air and indoor air are very important to human health. The average adult with a weight of 70kg inhales about 20m^3 of air per day (Curtis et al., 2017). Groups that are most sensitive to the health effects of outdoor air toxicants, according to the American Lung Association (2005) as cited by Curtis et al (2017), are asthmatics, atopic patients, patients with emphysema and bronchitis, heart and stroke patients, diabetes, pregnant women, the elderly and children (Curtis et al., 2017).

One of the major environmental problems affecting people all over the world is ambient or outdoor air pollution. Low, middle and high-income countries are all affected by the issue of outdoor air pollution. Ambient air pollution in short is a global environmental issue and a major threat to human health. In 2016, 4.2 million premature deaths worldwide per year was estimated to be caused by ambient air pollution in both rural and urban areas (WHO, 2018a). Those who are most vulnerable to the burden of air pollution are people living in low- and middle- income countries. Air pollution plays a very significant role cardiovascular illness and death. WHO estimates that in 2016, some 58% of premature deaths linked to ambient air pollution were due to ischemic heart disease and strokes, while 18% mortality was caused by chronic obstructive pulmonary disease and acute lower respiratory infections respectively, and 6% of deaths was caused by lung cancer (WHO, 2018a).

2.4 Pollutants of Major Health Concern

Many substances can be found in the atmosphere that can cause harm to humans, animals and the environment as a whole in high concentrations. These pollutants are different in nature and composition and they change from one place to another. Some pollutants however, are monitored more closely than others because their effects are known to be detrimental to health and the environment. The main air pollutants of major health concern are: Particulate Matter (PM), Nitrogen dioxide, Ozone, Sulphur dioxide, Carbon monoxide, Volatile Organic Compounds (VOC's), Lead and other heavy metals ("Air Polution and Health in Rapidly Developing Countries," 2001)

There are lot of international agencies and even countries that have developed a way to show the different concentrations of air pollution in different places across the world and this helps to alert people and governments when levels are high. One of these systems is one developed by The UK department of health. The concentration of each pollutant are graded and ranked at a level between 1 and 10 and then split into four categories; low, moderate, high and very high (European Lung Foundation, 2019).

2.4.1 Particulate Matter

Particulate Matter (PM) is an air pollutant made up of a mixture of very small particles and liquid droplets (acids, organic chemicals, metals and soil or dust particles) (Anderson et al., 2012). Sources of PM can be grouped into primary sources and secondary sources. Primary sources of PM are where particles are directly transported straight from the source and they can either be anthropogenic or natural. Man-made sources of PM include agriculture, vehicular emissions, burning of fossil fuel, burning of firewood in households, burning garbage, industrial activities like construction, manufacturing, mining and metal works, dust from untarred roads and wearing of brakes and tyres. Natural sources include volcanoes, fires, dust, and sea salt spray. Secondary particles are then formed afterwards in the atmosphere due to chemical reactions. This occurs through the production of substances with low volatility. PM is then formed when these substances compress into liquid or solid. Examples include sulphates and nitrates formed from the oxidation of Sulphur dioxide and nitrogen dioxide in the air, to acids.

The acids are then made ineffective by ammonia found in the atmosphere. (Kelly & Fussell, 2012).

PM is further categorized into particle size and composition. PM size can be grouped into fine PM and coarse PM. Particles that have a diameter of between 0.1 and 2.5μm and particles that are ultra-fine are called fine PM and are generally known as $PM_{2.5.}$ $PM_{2.5}$ is also called respirable particles because of their ability to enter deep into the alveolar gas exchange region of the lungs (Kelly & Fussell, 2012). Some sources of fine particles include burning of firewood and charcoal, vehicular emissions as well as industrial activities (Sulemana, 2016). Coarse particles are made up of particles that have a diameter greater than 2.5μm. They are usually referred to as PM_{10} or $PM_{10\text{-}2.5}$. These types of particles are mostly visible or obvious and examples are black smoke, soil, dust, sea spray salt particles, etc. Other sources are pollen, mold, spores and other plant parts. All ambient PM having a diameter of 10µm or less, that is, ultra-fine, fine and coarse are denoted by PM_{10}. They are referred to as "thoracic" particles because they can escape the initial defenses of the nose and throat and move beyond the larynx to transport along the airways in the thorax (Kelly & Fussell, 2012).

PM has both physical and chemical characteristics in terms of composition. PM is composed of chemical constituents such as sulfates, nitrates, ammonium, other inorganic ions such as ions of sodium, potassium, calcium, magnesium and chloride, organic and elemental carbon, crustal material, particle-bound water, metals, and polycyclic aromatic hydrocarbons (PAH). Biological components such as allergens and microbial compounds are also found in PM (Bae & Hong, 2018).

2.4.2 Effects of Particulate Matter Exposure ($PM_{10-2.5}$)

According to the World Health Organization (WHO), there is a close, computable link between exposure to high levels of particulates (PM_{10} and $PM_{2.5}$) and increased death or morbidity, both daily and in the long run. Even at very low concentrations, small particulates, that is PM_{10} and $PM_{2.}$5, have impacts on health (WHO, 2018a). This means that even when you are exposed to some kind of particulate pollutant, there is the possibility that you may experience some effects. So if even a small amount can harm you, imagine working in an environment polluted with particulates for a period of 8 hours daily. WHO therefore set guidelines aimed to achieve the lowest concentrations of particulate matter possible since no threshold below which no damage to health hasn't been identified yet. Particulate air pollution is harmful to all.

The WHO air quality guidelines for particulate matter are 10 µg/m^3 annual mean and 25 µg/m^3 24-hour mean for $PM_{2.5}$ and 20 µg/m^3 annual mean and 50 µg/m^3 24-hour mean

Particulate matter is one part of air pollution that is adamant when it comes to health issues in people everywhere. According to the WHO, approximately 800,000 premature deaths recorded yearly could be related to PM pollution (Sulemana, 2016) and it is ranked the 13^{th} leading cause of mortality globally. By the 1970s, the relationship between particulate air pollution and respiratory disease had already been established. This was made possible as a result of major air pollution incidents that have been recorded in history (Dockery, 2009). In a study to assess the relationship between long term exposure to fine particulate air pollution and all cause lung cancer and cardiopulmonary mortality, it was found that for each $10\mu g/m^3$ increase in particulate air pollution, there was an approximately a 4% and 8% increased risk in all-cause cardiopulmonary and lung cancer mortality respectively (Pope et al., 2002). In another study, 188,699 people who have never smoked before in their lifetime were selected from 1.2 million cancer prevention study participants and followed prospectively for 26 years. Results indicated that $10\mu/m^3$ increase in $PM_{2.5}$ concentrations was associated with 15-27% increase in lung mortality (Turner et al., 2011).

Studies on the long-term effects of severe PM exposure and acute effects of PM on cardiovascular mortality revealed that PM has significant health effects on the heart. Previous analysis showed that for any increase in death caused by PM, two thirds of the effect was justified by the cardiovascular diseases (Anderson et al., 2012). A close link between coronary artery disease and PM is established as PM causes coagulation of blood and platelet activation. A followed 65,000 post-menopausal women who have never had any heart disease before revealed that long-term PM exposure resulted in a 24% increase in CV diseases and 75% increase in CV mortality per $10\mu g/m^3$ increase in PM (Anderson et al., 2012).

CHAPTER THREE

3.0 METHODOLOGY

3.1 Profile of Study Area

Geographically Suame-Magazine can be located at latitude 6°46'00" North and longitude 1°38'00" West with an estimated population of 250, 365. It has a moist semi-deciduous forest vegetation and an annual rainfall of 1,300mm and temperature of 26°C. (Kodom, 2016).

It is situated to the east of the main road to the Northern Regions of Ghana on the side and bottom of a hill and to the west of a narrow and sheltered waterway. The area is approximately 1.8 kilometers long with an average width of 320 meters. Rapid development of workshops, stores, petrol stations and residential buildings has brought about an expansion to the area as the years go by. The perimeter of the area covers a distance of 7km currently. Six out of every ten buildings within the central part of the area are constructed mainly of wooden boards and iron sheets. The land is separated into zones for administrative and spatial planning purposes. SuameMagazine constitutes zones 1-7, 11, 12, 13, 18 and 19. The inconsistency in numbering these zones is as a result of poor demarcation of plots and the fast emergence of other magazines in Kumasi (Obeng, 2015). One of the very first noticeable features of the Suame-Magazine is the pungent smell of fumes in every part of the area. Other noticeable features and activities are the sale of car decoration items, sale of second-hand cars, manufacturing of carts, trolleys, engineering works, metal fabrication, lots and lots of scrap metals and the most obvious, several abandoned vehicles striped of most if not all of their parts. Due to the poorly planned state of the area with lots of slums and the many industrial activities that goes on makes Suame-Magazine the best site for this research.

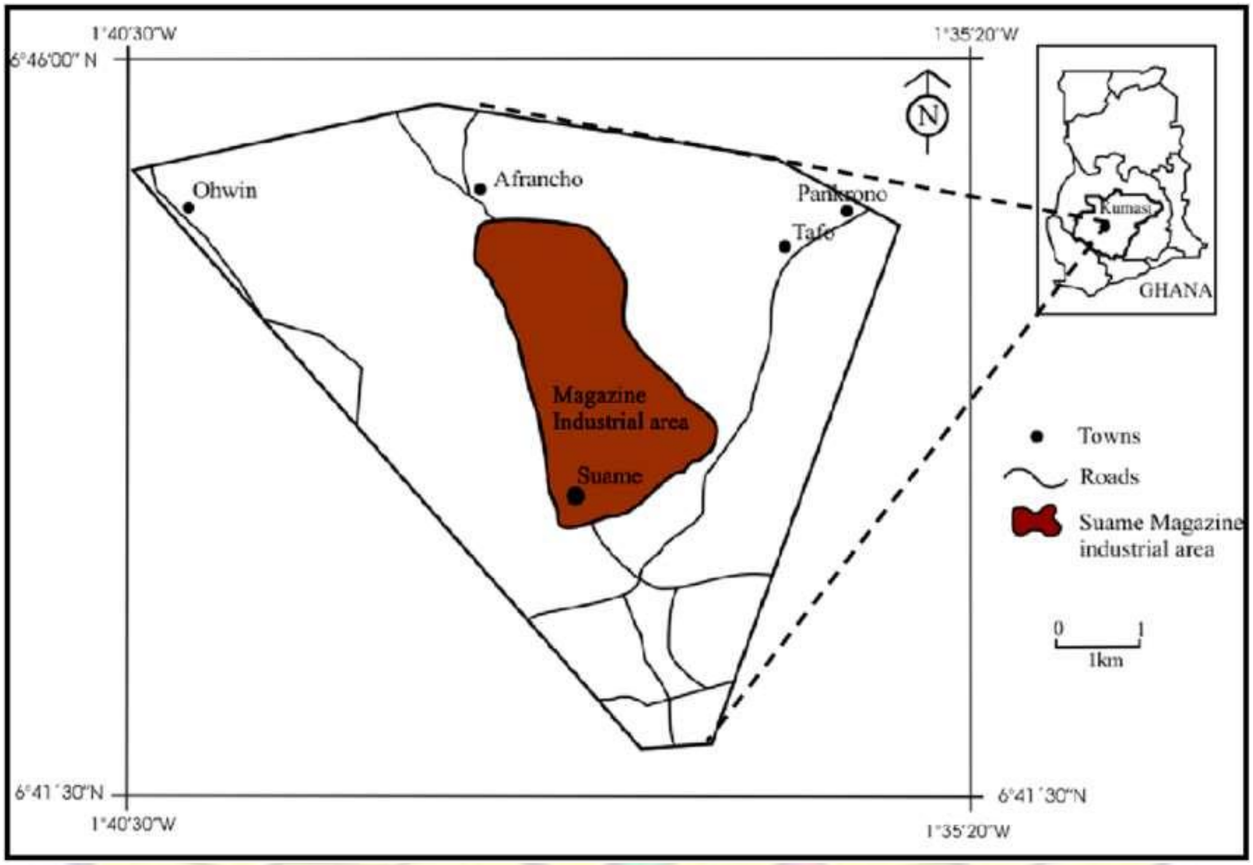

Figure 2.1: Map showing location of study area Suame-Magazine industrial area (Kodom, 2016)

3.2 Study Population and Sample Size

Suame Municipality has a total population of 250, 365 with over 200, 000 being the population of artisans. The area is further separated into zones with about 5000 artisans in each zone. The study was conducted in zone 21 and a sample of 102 artisans were recruited for the study based on those that were available at the time of the study.

3.3 Sampling

3.3.1 Inclusion Criteria

The following were criteria for inclusion for the study:

1. All local artisans and apprentices available at the time of the study.
2. Artisans that deal with manufacturing of food processing machinery, local utensils and ovens, metal fabricators and vehicle repairs.
3. Artisans and apprentices above the age of 18.
4. Artisans who work at least 5 days of the week.

3.3.2 Exclusion Criteria

The following were the criteria for exclusion for the study:

1. Customers that patronize their services
2. Workers below the age of 18
3. Workers who are absent most times in the week

3.4 Study Design

A descriptive cross-sectional study design was used to assess the health effects due to exposure to particulate air pollution on artisans at Suame-Magazine.

3.5 Sampling Technique and Data Collection

The Suame-Magazine enclave is separated into zones. Zone 21 was used for the study. Artisans were selected or chosen based on those that were available at the time of the study and this is because the total number of artisans at Suame-Magazine is not known due to the nature of the work. A residential area at Suame was selected randomly and used as the control of the study. An air sampling device was used to collect particulate matter (PM 10) at 3 different locations within Zone 21. Data collected was purely quantitative and collection was done by administering questionnaires that were answered by the artisans.

3.6 INSTRUMENTATION

Figure 3.1: Haz-Dust Model EPAM-7500

The HAZ-DUST EPAM-7500 is a portable lightweight monitor and air sampling device that measures particulate matter in both indoor and outdoor (ambient) air in real time.it has different sampling heads that can be changed depending on the type of particles being sampled. It can sample PM_{10}, $PM_{2.5}$, $PM_{1.0}$ or Total Suspended Particles (TSP). it can also be used for gravimetric sampling the use of filters for further analysis of metal and carbon content. Data can be transferred directly through USB, Ethernet or SD card.

3.6.1 Mode of Operation of the HAZ-DUST EPAM 7500

The air sampling device was placed at a height of two meters above the ground at each location at the study site. A PM_{10} sampling head was selected and fixed to the sensor. PM_{10} option was selected on the monitor to ensure that the correct particle size was sampled. Monitoring command was issued on the device to begin sampling. Dust particles are drawn into the sensor head at a flow rate of 2L/M and are detected once every second. Air sample was recorded every minute for a period of 8 hours. Dust concentrations are instantaneously calculated and displayed on the Haz-Dust EPAM-7500's LCD. All data points are stored in memory for later analysis.

3.7 Human Health Risk Assessment (HHRA)

Risk assessment is the process of deducing the potential impact of a chemical, physical, microbiological or psychosocial hazard on a particular human population or ecosystem under a particular set of conditions and for a certain period of time (DSE, 2016). HHRA is a useful tool to check human health risks due t exposure to a given environmental pollutant (Thabethe, Engelbrecht, Wright, & Oosthuizen, 2014). The risk assessment process comprises of four parts; hazard identification, exposure assessment, dose-response assessment and risk characterization.

Hazard Identification: the hazard identified in this study and also from existing literature was PM_{10} and the types of health risks associated with its exposure.

Dose-response Assessment: Dose-response assessment is referred to how an individual will react to a particular exposure. This assessment was not performed in this study because it requires extensive health screening and health data that cannot be obtained for the study as this is a student research thesis. The concentrations of PM_{10} were compared with the WHO air quality standard and the Ghana EPA standard for air quality. These standard values were used as a benchmark for the study.

Hazard identification: PM_{10} concentrations likely to cause harm were estimated using information obtained from hazard identification and exposure assessment during the study. The data obtained from monitoring the air at the study site were used to assess how the different levels of exposure to PM_{10} can affect the possibility and severity of health effects.

The route of exposure was assumed to be inhalation and exposure duration was 8 hours per day (normal working hours per day). The study sample was assumed to be exposed to PM_{10} concentrations higher than the Ghana EPA and WHO standards.

Risk Characterization: Risk characterization is used to estimate the risk posed by exposure to PM_{10} concentrations. Two equations were used to estimate the risk of exposure to PM_{10} (Thabethe et al., 2014)

Equation 1: Field Average Daily Dose (FADD):

$$\mathbf{FADD = C \times IR \times EF \times ED/BW \times AT}$$

Where:

FADD = Dose at which an artisan may be exposed to PM_{10} concentrations inhaled (μg/kg/day)

C = Average PM_{10} concentration (μg/m^3) (mean average concentration of the study site sample in μg/m^3, 211 μg/m^3)

IR = Inhalation Rate (volume of polluted air breathed in per unit time) (m^3/day). The 95th percentile inhalation rates for long-term exposures for an adult between the ages of 31-40 years is 21.4m^3/day (Epa, 2011)

EF = Exposure Frequency which is number of working days (243 days excluding holidays)

ED = Exposure Duration (years) (assumed to be 20 years from the demographics of the study questionnaire)

BW = Body Weight (70kg, average body weight of an adult)

AT = Averaging Time (period over which exposure is averaged in days)

= ED × 365 days/year for non-carcinogenic effect of human exposure (20 years × 365 days)

= LT × 365 days/year = 70 years × 365 days/year for effects that are carcinogenic. (assuming lifetime average, LT, is 70 years).

Equation 2: Safe Average Daily Dose (SADD)

SADD = C × IR × EF × ED/BW × AT

Where:

SADD is the dose at which an artisan will not be suffer any negative health risks in µg/kg/day. The Ghana and WHO standard for PM_{10} guideline value was be used as the concentration (70 µg/m^3-EPA Ghana value, 50 µg/m^3-WHO value).

The risk caused by exposure to PM_{10} was calculated using the **Risk Quotient (RQ)** or **Hazard Quotient (HQ)**

HQ = FADD/SADD

Where:

HQ = Hazard Quotient (no unit)

FADD = Field Average Daily Dose (µg/kg/day)

SADD = Safe Average Daily Dose (µg/kg/day)

HQ Guidelines

HQ <0.1: no hazard exists;

HQ 0.1-1.0: the hazard is low;

HQ 1.1-10: the hazard is moderate; and

HQ >10: hazard is high

3.8 STATISTICAL ANALYSIS

Data was analyzed using STATA. Chi square analysis was used to determine the association between particulate matter exposure and the health effects and outcomes. Simple one sample ttest was used to compare the means of the study site sample and the control site sample to WHO ($50 \mu g/m^3$) and EPA-Ghana ($70 \mu g/m^3$).

3.9 ETHICAL CONSIDERATION

Approval to carry out the study at Suame-Magazine was given by the Chairman of Suame Municipal Assembly and additional approval given by the chairman of the Suame Association of Garages. Consent was sought from participants before information was collected from them. Confidentiality and anonymity were assured. Ethical clearance was granted by the Committee on Human Research Publication and Ethics (CHRPE) at the Kwame Nkrumah University of Science and Technology before carrying out the study.

CHAPTER FOUR

4.0 RESULTS

This chapter presents the results for Particulate Matter (PM_{10}) concentrations after air was sampled at Zone 21 of Suame-Magazine and a residential area at Suame which was used as the control and the results from the questionnaires to assess health effects.

4.1 Demographic Characteristics of respondents

Table 4.1 Demographics

Demographics	Frequency (n=102)	Percentage (%)
Age (Years)		
≤ 20	1	0.98
21-30	25	24.51
31-40	41	40.20 15.69
41-50	16	18.63
Above 50	19	
Marital Status		
Single	6	5.88
Married	96	94.12
Level of Education		
No formal Education	55	53.92 23.53
Primary	24	17.65
JHS	18	3.92
SHS	4	0.98
O'Level	1	
Work Status		
Master Craftsman	36	35.29
Apprentice	66	64.71
Working Years		
Under 1 year	1	0.98
1-5 years	15	14.71 36.27
6-10 years	37	48.04
Above 10 years	49	
Work Duration		
5-8 hours	73	71.57
Above 8 hours	29	28.43

A total of hundred and two (102) questionnaires were administered. It is clear that this is a male dominated industry with 100% (102) of the study sample being men (0.98%). The youngest of the participants was between the ages of 18-20 (0.98%) and the oldest were above 50 years representing 18.63%. the rest were between the ages of 21-30 year, 31-40 years and 41-50 years also taking up 24.51%, 40.20%, 15.69% respectively. Among these men, 5.88% were single and

94.12% were married. The highest level of education was O'Level with 0.98%. Majority of the respondents had no formal education representing 53.92%. A few had basic primary, Junior high and Senior high education with 23.53%, 17.65%, 3.92% respectively. Master craftsmen were a total of 36 (35.29%) and apprentices were 66 (64.71%). Most working hours were between 5-8 hours (71.57%) and other times above 8 hours (28.43%) and the highest number of years worked was above 10 years (48.04%) and the shortest being under 1 year (0.98%).

4.2 PM_{10} Concentrations (PM 10 Sample from the study site, PM- sample for the control i.e. residential area at Suame**)**

Table 4.2 Descriptive statistics for the Exposure and the Control group

Descriptive Statistics		
	PM 10 Exposure (mg/m^3)	**PM 10 Control Group (mg/m^3)**
Mean	.211	.103
Std. Deviation	.493	.018
Minimum	.06	.062
Maximum	11.491	.286

From the table above, the average concentration for PM_{10} in the experimental group was $0.211 mg/m^3$ and that of control group was $0.103 mg/m^3$. The maximum concentrations for the experimental and control groups were $11.491 mg/m^3$ and $0.286 mg/m^3$ respectively. Standard deviation for the study group and the control group was 0.493 mg/m^3 and .018 mg/m^3 respectively.

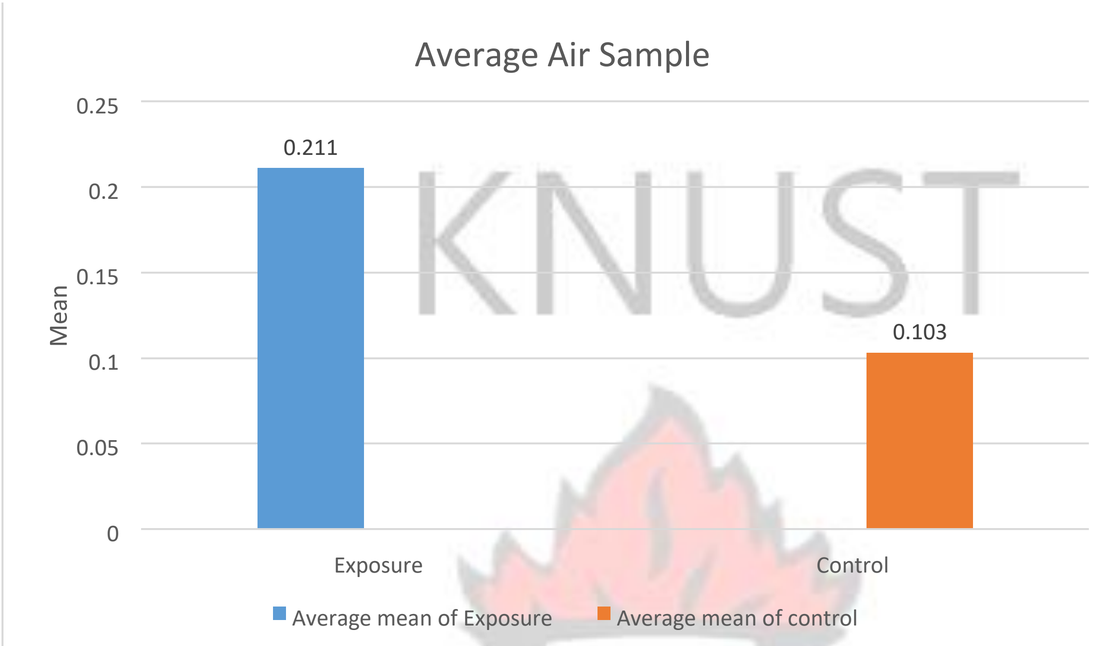

Figure 4.1: Bar graph showing the levels of the average mean concentrations of the study site sample and the control sample.

This bar graph gives a clear indication graphically that, the PM_{10} levels of samples taken from the study site (0.211mg/m^3) was higher than the samples taken from the site used for the control (0.103mg/m^3).

Table 4.3 Descriptive statistics for each of the samples taken at the Exposure and Control sites.

Samples	Counts per sample (Frequency) (n)	Minimum	Maximum	Mean	Standard deviation

Exposure 1 Sample (mg/m3)	423	.06	5.956	.239	.448
Exposure 2 Sample (mg/m3)	467	.087	11.491	.216	.701
Exposure 3 Sample (mg/m3)	465	.079	2.463	.181	.173
Control 1 Sample (mg/m3)	469	.077	.258	.101	.014
Control 2 Sample (mg/m3)	477	.062	.286	.101	.020
Control 3 Sample (mg/m3)	468	.082	.279	.107	.019

The table above shows clearly that the PM_{10} concentrations were high in all three samples taken at the study site compared to the concentrations sampled at the control site which was a residential area at Suame. The highest PM_{10} concentration sampled at the study site was 11.491mg/m^3 and the lowest concentration was 0.06mg/m^3. The highest and lowest concentration recorded among the control samples were 0.286mg/m^3 and 0.062mg/m^3 respectively.

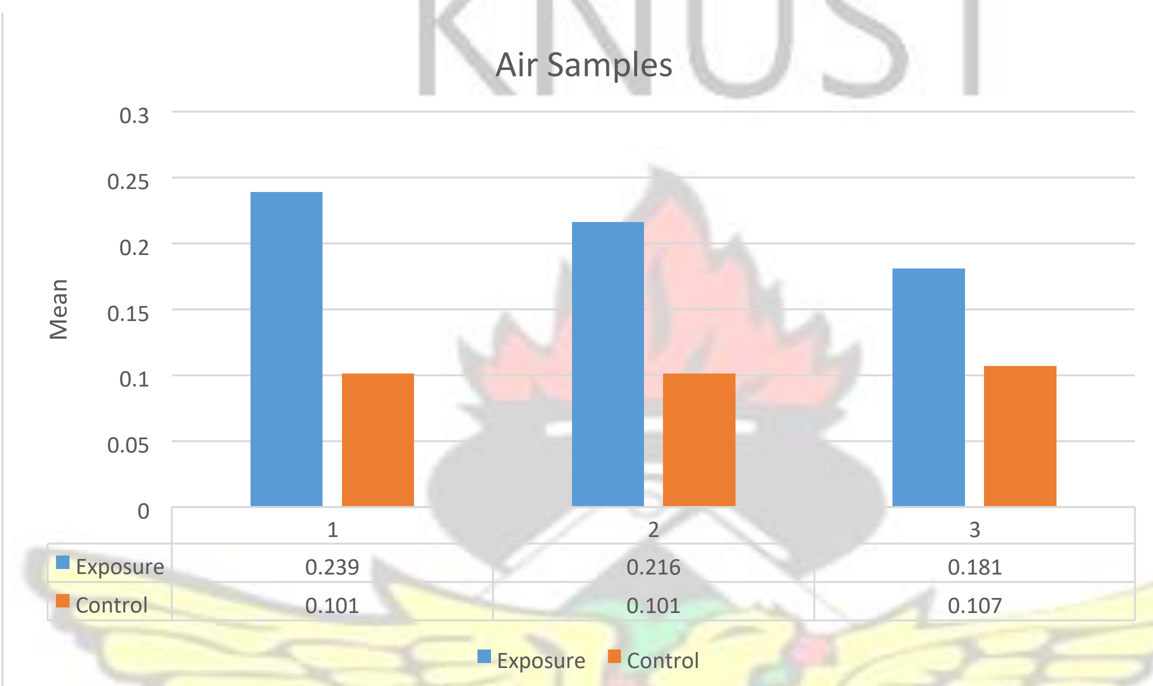

Figure 5.1: A bar graph showing the different levels of all the sample taken at both the study site and the control.

Table 4.4 Mean comparison test (t-test) of exposure and control against the Ghana-EPA standard

Variable	Mean	Confidence interval (95% confidence interval)		p-value
Ghana-EPA standard (0.07mg/m^3 or 70µg/m^3)				
Exposure	.211	.185	.237	0.0000
Control	.103	.102	.104	0.0000

The table below shows the results for a simple mean comparison test where the mean concentrations of the exposure and the control (211 µg/m^3 and 103 µg/m^3 respectively) were compared to the Ghana-EPA standard (70µg/m^3) at a p-value of 0.0000. Both concentrations were higher compared to the standard.

4.3 Human Health Risk Assessment at Suame-Magazine

Table 4.5 Results for Human Health Risk Assessment

FADD µg/m^3	SADD (WHO, 50µg/m^3), µg/m^3	SADD (GhanaEPA, 70 µg/m^3) µg/m^3	HQ (WHO, 50µg/m^3)	HQ (Ghana-EPA, 70 µg/m^3)	Risk Indication (WHO, 50µg/m^3)	Risk Indication (EPAGhana, 70 µg/m^3)
42.944	10.177	14.247	4.2	3.0	Moderate	Moderate

This table presents the Human Health Risk assessment of an adult male artisan between the ages of 31-40 years who has worked at the site for a period of 20 years for 243 working days with a body weight of 70kg (assumed body weight of an adult) and an inhalation rate of 21.4m^3/day. The FADD

(42.944 µg/m^3) was calculated using the mean average concentration of the study site sample and the SADD (10.177 µg/m^3 and 14.247 µg/m^3) were calculated using the Ghana-EPA and WHO guideline values (70 µg/m^3 and 50µg/m^3 respectively).

4.4 Assessing the relationship between exposure to PM_{10} emissions and Health effects of exposure.

All participants responded Yes to exposure to PM_{10} emissions constituting 100% of the total sample.

Table 4.6 Response to Health effects associated with the exposure to PM

Health Effects	Response	Frequency (n)	Percentage (%)
Cough	Yes No	49 53	48.04 51.96
Breathing difficulty	Yes No	34 67	34.31 65.69
Asthma	Yes No	6 96	5.88 94.12
Eyes, Throat, Nose Irritation	Yes No	57 45	55.88 44.12
Non-fatal Heart attack	Yes No	0 102	0 100
Hypertension	Yes No	27 75	26.47 73.53
Headache	Yes No	51 51	50 50
Other	Yes No	16 86	15.69 81.37

The two main health conditions of concern were lung disease and heart disease but none of them respondents reported knowing if they had a heart or lung disease. Other health outcomes that were experienced by the participants were coughs, breathing difficulty, asthma, eyes, throat and nose irritations, non-fatal heart attack, hypertension, headache as well as other health effects that were not related to the study. Out of the total sample, 49(48.04%) had experienced some headaches, occasionally 35(34.31) have had some breathing difficulties, only 6(5.88%) had asthma, 57(55.88%) had some eyes, throat and nose irritations, none of the participants has ever had heart disease, lung disease and non-fatal heart attack with 100% No responses, 27(26.47%) had hypertension, 51(50%) have had headaches and 16(15.69%) had other health effects unrelated to the study.

Table 4.7 Exposure (vehicle emission, smoke, dust, soot, fumes) and other health outcomes

Exposures and cough			**TOTAL**
	Yes	No	
Yes	49 (48.04%)	53 (51.96%)	102
Exposure and breathing difficulty			
	Yes	No	
Yes	35 (34.31%)	67 (65.69%)	102
Exposure and asthma			
	Yes	No	
Yes	6 (5.88%)	96 (94.12%)	102
Exposure and eyes, throat and nose irritations			
	Yes	No	
Yes	57 (55.88%)	45 (44.12%)	102
Exposure and Hypertension			
	Yes	No	
Yes	27 (26.47%)	75 (73.53%)	
Exposure and Headache			
	Yes	No	
Yes	51 (50%)	51 (50%)	102
Exposure and Death cases			
	Yes	No	
No	57 (55.88%)	45 (44.12%)	102

The association between exposure and the health effects was established by Chi-square analysis. Emissions was analyzed against lung disease, heart disease, cough, breathing difficulty, asthma, eyes, throat and nose irritations, non-fatal heart attack, hypertension, headache and other health effects. No p-value was generated due to the response to the exposures being one directional. All participants answered yes to exposures. None of the respondents had ever had a non-fatal heart attack and all reported having been exposed to the emissions and none of them reported having heart disease. Assessing the relationship between the exposure to PM_{10} and the number of death cases, a total of 57 responded yes and 45 responded No as seen from the above table. There was some association between exposure and death cases.

Table 4.8 Year of work and Breathing Difficulty

Years of work	**Breathing Difficulty (p-value=0.008)**	
	Yes	No
Under 1 year	0 (0.00%)	1 (0.98%)
1-5 years	3 (2.94%)	12 (11.76%)
6-10	7 (6.86%)	30 (29.41%)
Above 10 years	25 (24.51%)	24 (23.53%)
Work duration and Breathing difficulty (p-value=0.001)		
	Yes	No
5-8 hours	18 (17.65%)	55 (53.92%)
Above 8 hours	17 (16.67%)	12 (11.76%)

The table above shows the association between the number of years of work and breathing difficulty at a p-value of 0.008. The strongest association was above 10 years with 24.51% and the weakest was under 1 year with 0.98%. This same table shows the association between work duration and breathing difficulty at a p-value of 0.001. The strongest association was 5 to 8 hours work duration and the weakest was above 8 hours.

4.5 The major hazards identified by Respondents

Hazards faced by artisans daily are slips, trips, falls, cuts, punctures and noise. All 102 respondents selected all the hazards mentioned representing 100%.

Table 4.9 Explosive and reactive chemicals

Reactive or Explosive Chemicals	**Frequency (102)**	**Percentage %**
Yes	87	85.29
No	15	14.71

From the table, majority of the study participants representing 85.29% responded yes to working with reactive or explosive chemicals and 15 respondents representing 14.71% answered NO.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Particulate Matter

From table 4.1, it can be observed that the mean PM_{10} concentration was higher in the study site sample (0.0211mg/m^3 or 211µg/m^3) compared to the sample from the residential area which acted as a control. This is expected because of the extensive industrial activities such as metal fabrications, manufacturing of tools and equipment, local cooking utensils, automobile works like car body spraying, etc., that was being conducted at the site. The mean concentration of the control site was low (0.103 mg/m^3 or 103 µg/m^3). This value was not expected because a residential area at Suame was used as the control making sure there were no industrial activities present in the vicinity. This means that even though the concentrations were low compared to that of the study site, they were still high compared to the WHO and EPA-Ghana standards. Other factors such as the burning of refuse and the use of coal and firewood for cooking by some residents may have contributed to the concentration of the air sample. This implies that there is always some type of pollutant in the atmosphere but they may not be at levels of health concern. It can also be deduced from table 4.2 that the maximum value of PM_{10} concentrations among all samples taken from the study site was 11.49 mg/m^3 or 11,491 µg/m^3 and the minimum value recorded was 0.06 mg/m^3 or 60 µg/m^3. It can be observed that the maximum value recorded for the control site was 0.86mg/m^3 or 860 µg/m^3 and the minimum value recorded was 0.062mg/m^3 or 62 µg/m^3. The mean average concentration of the study site was very high compared to the WHO air quality standard (50 µg/m^3) and EPA-Ghana standard (70 µg/m^3). Other factors such as burning of rubbish and firewood for cooking at various points at the control site may have influenced the high concentrations recorded. According to Tyagi et al. (2012) as cited by Sulemana (2016), PM_{10} concentrations could be increased by biomass burning by 10-100 times more than other sources of fuel (Sulemana, 2016).

A one sample t-test was run to determine whether the mean PM_{10} concentrations of both the study site and the control site was different to the normal or acceptable concentrations. The concentrations were compared to the WHO and EPA-Ghana standards. The test was found to be significant and hence there are significant differences between the concentrations of both the study site and the control site compared to the WHO and EPA-Ghana standards. Thus based on the two guidelines from WHO and EPA-Ghana, the ambient air of both study site and control site were polluted with particulate matter.

This finding was not different from results from other studies. Sulemana (2016), found high concentrations of PM_{10} at traffic sites in Accra in a study to assess the heavy metals present in particulate matter (Sulemana, 2016). In another study by Air et al (2010), indoor and outdoor PM_{10} and $PM_{2.5}$ concentrations that were measured during winter and summer in 15 homes in an industrialized area called Kocaeli in Turkey, were found to be at very high concentrations (Air, Wiley, & Air, 2010). Kozah 2016 found high levels of particulate matter when measuring Atrazine levels in particulate matter in Kumasi Metropolis (Kozah, 2016).

5.2 Human Health Risk Assessment

From the results of the risk assessment in table 4.3, based on the guidelines for interpreting Hazard Quotient (HQ), where if HQ is less than 1, no hazard exists, if HQ is between 0.1 and 1.0, the hazard is low, if HQ is between 1.1 and 10, hazard is moderate and if HQ is greater than 10, hazard is very high (Thabethe et al., 2014), the HQ where the WHO and EPA-Ghana standard values were used to calculate the SADD was 4.2 and 3 respectively. This implies that the risk of exposure to particulate matter through inhalation to an artisan between the ages of 3140 with a body weight of 70kg and works 243 days in a year for a period of 8 hours daily is moderate. A moderate indication means that there is some risk but it is not at an alarming level. Bear in mind a moderate indication is close to a high indication and it still has to be considered with some seriousness. Precautions and safety measures should be put in place to reduce the risk.

A similar assessment was done in a study in a low socio-economic community in South Africa. The study assessed the health risks posed to PM10 exposure among an infant, child and an adult. It was found out that infants were exposed to higher dose of PM_{10} compared to the other life stages but at the same concentrations of PM_{10} they were at the same risk of developing detrimental health outcomes from exposure (Thabethe et al., 2014).

5.3 Association between exposure to PM_{10} Emissions and Health Effects.

The types of emissions that the artisans are exposed to are vehicle emissions from exhausts, smoke, sook and fumes. All the participants responded Yes to exposure to PM emissions which implies that they are all exposed to these emissions in one way or the other through their activities. A Chi-square analysis was run to check the relationship between the exposure to emissions to health effects. No p-value was generated because of the response to the emissions which was one directional that is all respondents replied Yes to exposure of emissions, so the next to do was to check the relationship between the exposure and the health outcomes. The major health conditions were heart and lung disease and other health Outcomes were, coughs, breathing difficulty, asthma, eyes, throat and nose irritations, non-fatal heart attack, hypertension and headache. It can be observed that although all respondents answered yes to the exposure there was no relationship between the exposure and the lung and heart disease although from literature particulate air pollution causes respiratory and cardiovascular effects and mortality. There was however some kind of relationship established between the exposure and coughs, breathing difficulty, eyes, throat and nose irritations, hypertension and headache.

An association was established between the years that an artisan has worked and breathing difficulty at a p-value of 0.008 which is less than the significant value ($p< 0.05$). This implies that a working experiencing some breathing difficulty may be due to how long the he has worked in that PM_{10} contaminated air. Work duration also plays a role where a worker experiences some health outcomes like breathing difficulty. An association was established between work duration and breathing difficulty at a p-value of 0.001 which is less than the significant value ($p< 0.05$). This means the test is statistically significant and a worker may experience some breathing difficulty in the course of doing his work. There was also a relationship established between exposure to particulate matter and the number of death cases reported but the setback was that no information was collected on the cause of death as all respondent did not know.

There has been several epidemiological studies and review papers written on the health effects of particulate matter exposure across the world. At study conducted in the Netherlands revealed that long-term exposure to pollution from traffic increased mortality by 71% (Anderson et al., 2012). According to Curtis et al (2017), air pollution sources such as industrial pollution and pollution from power plants fueled by coal may be a trigger to asthma and other respiratory diseases (Curtis et al., 2017). Peters et al (2000) as cited by Curtis et al (2017) reported that out that higher levels of airborne NO_2, CO and particulates were significantly associated with cardiac arrhythmias. This was found in a study of 100 patients in Massachusetts (Curtis et al., 2017)

5.4 Hazard Identification

The main hazards associate with the activities of the artisans were slips, trips, and falls, cuts, punctures and noise. Some of the artisans like the welders work with gas filled cylinders to help them melt the metals. This is a very serious hazard as it can explode and cause a lot of harm and injury and even death. The workers at the foundry work directly close to extreme heat and if the proper precautions are not taken it will result in accidents. The workers do their best to protect themselves by wearing safety boots and thick clothing. But that is not always the case. The only protection a sprayer has is just an old shirt which is used to cover his nose. There are pieces of scrap metals broken glasses and many obstacles found all over the site that could cause serious accidents. I was told stories where some workers lose their limbs due to some of these hazards.

CHAPTER SIX

6.0 CONCLUSION AND RECOMENDATION

6.1 CONCLUSION

- This study revealed that there was high Particulate Pollution (PM_{10}) in the ambient air due to the activities of artisans at Suame-Magazine compared to that of a residential area also at Suame.
- There was also some association between exposures to particulate pollutants and some health effects experienced by the artisans.
- The risk posed to an artisan working at Suame-Magazine was moderate.
- Some hazards identified were cuts, punctures, eye irritations, slips trips and falls and noise.

6.2 RECOMMENDATION

Recommendation for artisans

High particulate matter concentrations suggests the need for regulatory bodies to monitor the air regularly especially in industrial areas where pollution is high due to the activities. Workers should go for regular hospital checkups to make sure that they are healthy and for early detection of health effects. Workers should take the proper precautions by wearing Personal Protective Equipment such as thick hand gloves and boots, goggles, nose masks. Explosive chemicals should be stored properly and away from people.

Recommendation for future research

More research needs to be carried out in the area of particulate matter and workers' health and this is expected to influence policy makers in decision making on air pollution. Also air quality at the residential area should be looked into.

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