

**AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND
ENTREPRENEURIAL DEVELOPMENT**

**OCCUPATIONAL HEALTH HAZARDS AND HEALTH RISKS AMONG
QUARRY WORKERS IN THE GOMOA EAST DISTRICT, GHANA**

DORIS ADWOA DENTEH

2025

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BY

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**A thesis submitted to the School of Graduate Studies, Akenten Appiah-Menka
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fulfillment of the requirements for the award of a Master of Philosophy degree in
Environmental and Occupational Health Education.**

MAY, 2025

DECLARATION

I hereby declare that this thesis, with the exception of quotation and references contained in published works which have been duly acknowledged; is the result of own original work and that no part of it has been presented for another degree in this university or elsewhere.

Doris Adwoa Denteh

Signature: Date:

Supervisors' Declaration

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

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ABSTRACT

Quarry workers deal with loud noise, constant vibration, and lots of dust, which can lead to auditory impairment, lung diseases, and muscle and joint pains. The study assessed occupational hazards and health risk among workers in selected quarry companies at Gomoa East District. An analytical survey purposively examined 102 consenting quarry workers, conveniently recruited at two quarry sites in Ghana. Socio-demographic and occupational health and safety practices (OHSP) data were collected using a structured questionnaire and sound level meter data logger and air quality monitor were used to determine noise levels and particulate matter (PM), respectively. Descriptive statistic and ANOVA analysis were performed using SPSS version 25. Also, sound levels and particulate matter concentrations were compared to the permissible limits prescribed by EPA, Ghana. All the quarry workers were male with 80.4% pre-tertiary education. Majority (81.4%) were involved in site preparation, drilling, blasting, transportation, and truck loading. Predominant health hazards included musculoskeletal injuries, falls, and blasting accidents. All participants used some PPE like helmets, earplugs, gloves, and wellington boots. Noise levels were higher at the crusher area than the security post but below Occupational Safety and Health Administration's (OSHA) 85 dB limit. $PM_{2.5}$ levels at both quarry sites ranged from 16.56 to 43.37 $\mu\text{g}/\text{m}^3$ at both working areas, higher than the World Health Organization's (WHO) permissible limit. The average PM_{10} and $PM_{2.5}$ concentrations were 150 $\mu\text{g}/\text{m}^3$ and 80 $\mu\text{g}/\text{m}^3$, respectively, indicating significant health risks with Hazard Quotient values of 3 for PM_{10} and 3.2 for $PM_{2.5}$. Although all participants reported using some form of PPE, a substantial proportion

indicated minimal access. The noise level at the quarry sites exceeded the safe limit for prolonged exposure, indicating that workers were at risk of noise-induced hearing loss. The PM levels at the crusher areas exceeded WHO limits but were within Ghana's daily standards. Quarry companies should ensure the availability and accessibility of all necessary PPEs to their workers to minimize occupational hazards such as auditory damage, respiratory and cardiovascular issues.

KEYWORDS: Occupational Health and Safety Practices, Noise Level, Particulate Matter, Quarry work.

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DEDICATION

I dedicate this work to my dearest parents and lovely siblings for their inspirations, supports, and encouragement throughout my study.

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LIST OF ACRONYMS

ADD	Average Daily Dose
COPD	Chronic Obstructive Pulmonary Disease
DALY	Disability-Adjusted Life Years
dB	decibels
DBP	Diabolic Blood Pressure
EPA	Environmental protection agency
FEV	forced expiratory volume
FVC	forced vital capacity
HNIHL	Noise-Induced Hearing Loss
HQ	Hazard Quotient
ILO	International Labour Organisation
MSHA	Mine's Safety and Health Administration
NIHL	Noise-Induced Hearing Loss
OEL	Occupational Exposure Limits
OHS	Occupational Health and Safety
OHSP	Occupational Health and Safety Practices
OSH	Occupational Safety Hazard
OSHA	Occupational Safety and Health Administration
PEF	Peak expiratory flow
PM	Particulate Matter
PPE	Personal Protective Equipment

SBP	Systolic Blood Pressure
TSP	Total Suspended Particulate Matter
TWA	Time weighted average
WHO	World Health Organization

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Quarry or aggregates (crushed stone, sand, and gravel) is among the most used natural material (Kumari et al., 2024). They are required in the form of unbound materials or as ingredients of ready-mixed concrete or asphalt products for new construction projects or the repair of existing ones (Escavy *et al.*, 2022). On a global scale, natural aggregates can be considered an endless natural resource; nevertheless, some locations may experience supply constraints owing to overexploitation or sterilization of resources, which could have major economic, social, and environmental ramifications (Přikryl & Environment, 2021). Furthermore, due to the immediate productive gains connected with quarry activities, the quarry business is expanding at an increasing rate in most emerging countries, usually with little or no regulation (Kafu-Quvane et al., 2024).

In Ghana, for example, rapid infrastructure growth combined with high unemployment has resulted in a massive reliance on quarry activities (Baah-Ennumh et al., 2021). This is because infrastructure development is heavily reliant on the use of crushed rock aggregates. Building new infrastructure and fixing old roads, highways, bridges, airports, seaports, waste treatment facilities, water and sewer systems, and both private and public buildings require a large amount of crushed rock aggregates (Baah-Ennumh et al., 2021). However, research has revealed that, if not adequately managed, the expansion of quarry activities could pose serious health risks not only to quarry workers but also to residents

of quarry communities (Asante et al., 2014; Mensah et al., 2024). The chemicals and dust produced during quarrying can cause health problems like dizziness, breathing difficulties, fever, and eye irritation in people (Ata-Era, 2015). Mensah *et al.* (2024) explain that any chemical compounds inhaled can harm the respiratory system. For instance, breathing in dust can cause silicosis, a serious lung disease that can be fatal. Suspended dust particles can lead to asthma, lung cancer, heart problems, and even early death (Alemayehu et al., 2020). Fine dust is particularly harmful, as it can worsen respiratory conditions like asthma and affect people with arthritis (Ritz et al., 2019).

The above quarry-related issues may be the result of activities that generate substantial volumes of noise, dust, and chemical waste (Asante et al., 2014; Mensah et al., 2024). Quarrying produces a significant amount of dust, with particles ranging from 1 to 75 microns in size (Henry et al., 2017). Dust particles smaller than 50 microns, known as Total Suspended Particulate Matter (TSP), can stay in the air, while those smaller than 10 microns (PM10) can travel long distances and enter the human respiratory system (Alias et al., 2007).

Furthermore, noise is usually produced as a result of operations associated with stone extraction. Quarry operations, by definition, necessitate the use of machinery and equipment that make a lot of noise (Azman et al., 2022). High levels of noise in general, and quarry operations in particular, have been linked to hearing impairment (Henry et al., 2017).

1.2 Problem Statement

Quarry workers face significant occupational health risks due to prolonged exposure to harmful environmental conditions such as excessive dust, high noise levels, and physical strain. These exposures have been linked to serious health issues, including respiratory disorders, hearing loss, and musculoskeletal problems like chronic back pain (Jobin et al., 2017). In Ghana, studies have shown that dust concentrations at quarry sites, such as Odugblase (125.0 g/m³) and Klo-Begoro (109.3 g/m³), far exceed the Environmental Protection Agency (EPA) Ghana's recommended limit of 70 g/m³ (Asante et al., 2014). Moreover, workers are frequently exposed to hazardous noise levels from heavy machinery, further increasing the risk of noise-induced hearing loss (Gyamfi et al., 2016; Thurston, 2013).

Despite these evident health hazards, limited research in Ghana has assessed the extent of quarry workers' exposure to dust and noise or evaluated the effectiveness of safety practices in mitigating these risks (Mensah et al., 2020). This research gap underscores the urgent need to investigate the occupational health hazards associated with quarry operations in Ghana, particularly focusing on dust and noise exposure, and to assess the safety measures in place to protect workers.

1.3 Research Objectives

The main aim of this study is to assess occupational hazards and health risk among workers in selected quarry companies in the Gomoa East District.

Specifically, the study seeks to:

1. Examine occupational health and safety practices among quarry workers.
2. Determine noise levels at the work places.
3. Determine the concentration and characteristics of particulate matter at the work places.
4. Determine health risk levels associated with occupational exposures to noise and particulate matter concentrations at the work places.

1.4 Research Questions

The study was guided by the following questions:

1. What are the workplace health and safety practices among the quarry workers at the quarry sites?
2. What are the noise levels at work place?
3. What are the concentration and characteristics of particulate matter at work place?
4. What are the health risks linked with occupational exposures to particulate matter and noise at work place?

1.5 Justification

Occupational exposure to environmental hazards such as excessive noise and airborne particulate matter has been linked to a range of adverse health effects, including respiratory diseases, hearing impairment, and musculoskeletal disorders. Globally, quarrying activities are associated with poor working conditions and inadequate safety standards, making workers vulnerable to occupational injuries and illnesses (Jobin et al., 2017). Prolonged exposure to dust particles, especially respirable crystalline silica, can

lead to lung diseases such as silicosis and chronic obstructive pulmonary disease (COPD), while continuous exposure to high noise levels significantly increases the risk of permanent hearing loss (Gyamfi et al., 2016).

In Ghana, the Environmental Protection Agency (EPA) has set permissible limits for dust and noise exposure; however, studies have shown that these limits are frequently exceeded at quarry sites (Asante et al., 2014). Despite this, there is limited data on occupational exposures and their health implications among quarry workers, particularly in districts such as Gomoa East. Most available studies have been conducted in larger cities or highly industrialized areas, leaving a critical gap in understanding the occupational health landscape in other rapidly developing regions.

Moreover, there is a lack of systematic assessment of safety practices in quarry operations in Ghana, which may be contributing to the high incidence of work-related health conditions. This study aims to fill this gap by evaluating both the levels of hazardous exposures and the effectiveness of occupational safety practices in selected quarry companies within the Gomoa East District. The findings will provide relevant data to inform local and national occupational health policies and reinforce the need for stricter regulatory oversight and improved workplace safety standards. Ultimately, the study seeks to contribute to the protection and promotion of quarry workers' health and well-being.

1.6 Significance of the Study

The study seeks to assess noise levels and particulate matter concentrations at some selected quarry sites in the Gomoa East District of the Central Region, Ghana. The results of the study will therefore provide an understanding of the levels of these two important hazards associated with quarry activities to enable responsible bodies such as management of the quarry sites and state institutions such as the EPA to take steps to control their levels. Also, the study will assess occupational health and safety practices among the workers. Any gaps in the practices that will be identified from the study could serve as an important avenue for management of the quarry sites to take steps to promote adherence to health and safety measures. Finally, the study will contribute to the growing body of literature on occupational exposures among quarry workers in Ghana.

1.7 Scope of the Study

This study encompassed cohort of quarry workers within the study area, specifically those quarry companies in the Gomoa East District. Eligible participants were required to be a full-time worker in the working age group (18-65 years) that had worked in the study sites for at least 6 months. All gender was included.

1.8 Thesis Organisation

The study is divided into six main chapters. The first chapter addresses the background of the study, the problem statement, objectives, research questions, significance of the study, scope and organization of the study. In the second chapter, relevant literature related to this research topic was thoroughly examined. Chapter three focuses on presenting the

study area and the methodology employed to conduct the research. Moving on to chapter four, the study data is presented. Chapter five discussed the findings of the study. Lastly, in chapter six, the summary of the results is presented, along with drawing conclusions based on the key findings and offering recommendations based on the study's outcomes.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter comprehensively reviews existing literature related to occupational hazards associated with quarry in the mining industry globally and in Ghana. The following areas are covered in this review; occupational health and safety practices among quarry workers, noise levels at work stations and general work environment, particulate matter at workplace and general work environment. And lastly the health risks associated with occupational exposures to particulate matter and noise among quarry workers.

2.2.1 Quarrying

The quarry industry remains a vital part of the global economy, contributing significantly to human well-being and supporting sectors like construction and agriculture (Ismail et al., 2013). While industries have been developed to meet various human needs throughout history, many have negative impacts on human health. Despite the fact that 160 million people worldwide suffer from preventable occupational diseases each year, efforts to raise awareness and address workplace health and safety issues are still limited (Themann & Masterson, 2019). The United States Mine Safety and Health Administration (MSHA) reported that 37 quarry workers were seriously injured in non-metal quarrying accidents in 2015 across United State. Similarly, Safe Work Australia noted that although the fatality rate in the industry decreased from 12.4 in 2003, the

number of deaths increased from 4.4 in 2014 to 9 on average in 2015 (Themann & Masterson, 2019).

Quarrying is the extraction of minerals and precious metals from the earth and when vast amounts of commercially viable minerals on rocks are discovered near the earth's surface, quarries are created (Yusuf et al., 2022).

To generate crushed stone for building, the quarrying processes includes mining, rock explosion, crushing, and milling. The enormous rocks from the mountains are reduced in size, and there remain remnants of the quarrying operation (Prabhakar, 2012). The quarry industry is divided into two main sectors: dimension stone and crushed stone. The dimension stone sector focuses on extracting large blocks of rock in various sizes and shapes, used for building materials, monuments, paving, curbing, countertops, roofing, flagstones, and other projects needing large, uniform slabs. The crushed stone sector involves producing smaller, broken-down stones (like gravel and particulate matter) used as basic materials in construction, chemicals, paint, and metallurgy (Prabhakar, 2012).

Much of quarry work involves operating complex heavy machinery and equipment, with various tasks performed in a fast-paced environment where workers often stand for long periods. They frequently have to stand, stoop, bend, and make repetitive movements in uncomfortable positions (Thurston, 2013).

Quarrying is a dangerous job that presents serious environmental, health, and safety risks. Workers are at risk of accidents and illnesses due to factors like fatigue, poorly designed tools, challenging terrain, exposure to harsh conditions, and the use of explosives and machinery without proper safety precautions (Wanjiku, 2015).

Given the dangers of quarry work and often remote locations, access to medical care is crucial, yet many developing countries, including Ghana, lack these essential services. Many quarry sites have inadequate sanitation, unsafe drinking water, and other basic necessities, increasing the risk of health problems and disease. Workers are also more exposed to risks due to limited knowledge about resource scarcity, hazard identification, and risk management, and they often miss out on labor and health inspections (Chepchumba, 2020).

2.2.2 Occupational Health and Safety Practices Associated with Quarrying

Processes

The International Labour Organisation (ILO) reports that work-related injuries causes about 3 million and 400 million mortality and nonfatal injuries globally per year, respectively (Noman et al., 2021). This issue has a significant economic impact, costing about 4% of global GDP annually as a result of inadequate work-related safety and health practices (Noman *et al.*, 2021). In the United States, for a decade, the mining industry reported about 250 and 40,000 fatalities and nonfatal injuries, respectively. The Mine Safety and Health Administration (MSHA) determined that the majority of fatal incidents

in this industry happened when workers were operating quarry machinery and equipment (Bae *et al.*, 2021).

To effectively address potential hazards in safety programmes, managers need to identify risks related to equipment and assess workers' abilities in recognizing and preventing these hazards (Catherine, 2023). The Occupational Safety and Health Administration (OSHA) emphasizes that the purpose of safety training and education is to increase awareness of workplace hazards among both workers and managers and to promote their active participation in eliminating these risks before accidents occur (Jamil *et al.*, 2018). Surface mining safety training is tailored to provide quarry workers and managers with the essential skills and knowledge required to perform quarry operations safely, addressing the various hazards they might face on the job. This training can include formal classroom instruction, safety inspections, peer-to-peer training, and on-site demonstrations (Jamil *et al.*, 2018).

A study in Kenya found that natural radionuclides and their decay products are usually identified in the earth layer, including in quarry soil (Catherine, 2023). These radionuclides aren't evenly spread in the quarry environment; as they decay, they emit harmful ionizing radiation that can lead to cancer and other health issues (Kanayochukwu *et al.*, 2022).

2.2.3 Environmental Issues Resulting from Quarry Activities

Quarrying activities significantly impact the environment, affecting land, water, and air quality. About 45% of the global population lacks access to land (Bewiadzi *et al.*, 2018). In developing countries, over 500 million people are compelled to work in small-scale mining and quarrying to make a living (Rugulies *et al.*, 2021). Access to natural resources is vital for livelihoods in regions like Africa, East Asia, Southeast Asia, and Latin America because formal job opportunities are limited in these areas (Bewiadzi *et al.*, 2018).

Kibii, (2020) highlight that inhaling dust is associated with several respiratory diseases, including pneumoconiosis, silicosis, byssinosis, grain fever syndrome, occupational asthma, and farmer's lung. With the ongoing expansion of industrialization worldwide, occupational lung diseases are becoming increasingly prevalent (Kibii, 2020). Occupational health concerns impact not only individual workers but also the workplace and the broader work environment (Peckham et al., 2017). The characteristics of the work environment can differ significantly based on factors like the type of economic activity, occupation, company, and workplace size, with geographic and climatic conditions playing a major role in outdoor work settings. Workers in industries such as sandstone quarrying, the agate industry, slate-pencil cutting, and ceramics are particularly exposed to silica dust (Peckham et al., 2017).

Quarrying companies face ongoing challenges in managing environmental impacts, such as noise pollution from heavy machinery, blasting, and other sources. Blasting can lead to

high noise levels, dust, and even damage to nearby structures (Henry et al., 2017). Additionally, quarry operations significantly affect invertebrate communities, leading to habitat destruction and species extinction (Addae et al., 2020). Arthropods, including butterflies, are important indicators of environmental changes such as pollution and habitat loss. The land degradation caused by stone quarrying in Ghana has raised concerns about whether such activities should continue (Addae *et al.*, 2020).

2.2.3.1 Particulate Matter

Particulate matter are toxic mixture of solid and liquid particles in ambient atmosphere (Duan *et al.*, 2022). Sulfate, nitrates, ammonia, sodium chloride, black carbon, mineral dust, and water are the main constituents of PM.

Coarse Particulate Matter (PM₁₀)

These particles have diameters of 10 micrometers (μm) or less. Although they can be inhaled, they are generally less likely to reach deep into the lungs compared to smaller particles.

Fine Particulate Matter (PM_{2.5})

These particles have diameters of 2.5 micrometers (μm) or smaller. Due to their small size, they can penetrate deeply into the respiratory system, reaching the lungs and potentially entering the bloodstream.

Particles with a diameter of 10 microns or smaller (\leq PM10) can penetrate deeply into the lungs, but those with a diameter of 2.5 microns or smaller (\leq PM2.5) are even more hazardous to health (Who *et al.*, 2021).

Prolonged exposure to air pollution has been associated with numerous chronic health conditions. Specifically, exposure to particulate matter with a diameter of 2.5 μm or smaller (PM2.5) has been linked to various health issues, such as coronary heart disease, stroke, and diabetes (Kirby-McGregor *et al.*, 2022).

Increasing evidence and awareness about the harmful effects of air pollution on health have led to more efforts to reduce air pollution. Consequently, the World Health Organisation has updated its guideline for PM2.5 air quality, reducing the annual average limit from 10 $\mu\text{g}/\text{m}^3$ to 5 $\mu\text{g}/\text{m}^3$ (Kirby-McGregor *et al.*, 2022). Dust is a prominent and intrusive effect of quarrying that can be quite irritating. It not only causes visible pollution but also poses radiological and health risks to workers, the public, and the environs (Abdullah *et al.*, 2019).

2.2.3.2 Chemical Composition of Quarry Dust

Crushed stone production yields three main products: coarse aggregate (crushed stone) with a particle size 4.75 mm to 75 mm, fine aggregate with a particle size of 5-0.16 mm, and quarry dust with particles smaller than 0.16 mm (Henry *et al.*, 2017). Quarry dust is created through the mechanical processing of bulk materials for economic purposes, including extraction, handling, processing, storage, and transportation. Coarse aggregate

is commonly used in concrete production and as road ballast (Henry et al., 2017). The extraction of aggregates, coal, and other minerals generates significant amounts of waste due to factors such as natural resource contamination and the presence of overburden and fault zones (Ramesh et al., 2014).

Manimaran et al. (2017) conducted a study exploring the substitution of coarse aggregate with bamboo and fine aggregate with quarry dust in concrete. The research provided an overview of the mineralogical and chemical characteristics of granite rock, which are outlined in Table 2.1 below.

Table 2.1: Chemical Properties of Quarry Dust and Natural Sand

Constituents	Quarry Dust (%)	Natural Sand (%)
Silicon dioxide (SiO ₂)	65.73	82.37
Aluminum oxide (Al ₂ O ₃)	19.41	8.23
Iron oxide (Fe ₂ O ₃)	5.27	1.39
Calcium oxide (CaO)	3.64	2.79
Magnesium oxide (MgO)	2.16	1.47
Sodium oxide (Na ₂ O)	Nil	1.63
Potassium oxide (K ₂ O)	2.26	1.81
Titanium dioxide (TiO ₂)	1.28	Nil
Loss of ignition	0.35	0.31

According to chemical composition analysis, quarry dust has lower chemical composition values than natural sand. The Ghana Standards Authority states that quarry dust is mainly composed of silica (SiO₂), free silica, alumina (Al₂O₃), magnesium oxide (MgO), and sodium oxide (Na₂O), with silica being the most abundant component.

2.2.3.3 Human Health Risk Assessment of Particulate Matter

Increasing research in toxicology, epidemiology, and related fields has demonstrated a direct link between respirable particles and the onset of various diseases and higher mortality rates (Xing et al., 2016). Air pollution is intensifying, and its impact on human health is becoming increasingly critical. This pollution consists of both gaseous pollutants and particulate matter (PM). The health impacts of PM vary based on factors such as size, composition, origin, solubility, and their potential to produce reactive oxygen species (Kelly & Fussell, 2012). Particulate matter with an aerodynamic diameter of less than 2.5 μm (PM_{2.5}) poses a considerable health threat. These fine particles can bypass nasal defenses, penetrate deep into the respiratory system, and accumulate in the lungs, potentially affecting other body systems through lung air exchange. PM_{2.5} pollution is associated with serious health conditions, including cardiovascular and respiratory diseases, cancer, adverse birth outcomes, and Type 2 diabetes, and it also has negative effects on the climate (Farahani et al., 2022).

A 2022 report from the WHO estimated that fine particulate matter (PM_{2.5}) led to 4.2 million premature deaths globally in 2019 (Yang et al., 2022). It is essential to comprehend how PM_{2.5} affects health to prevent, diagnose, and treat dust-related illnesses and to advance more effective treatment strategies and technologies.

2.2.3.4 Noise Pollution

The World Health Organisation identifies noise as a public health concern affecting not only those exposed to it but also the propagation and source of the noise itself (WHO,

2021). Noise is classified as a form of toxic pollution, and numerous studies have linked it to various health problems, including irritability, difficulty concentrating, insomnia, and headaches (Yang et al., 2022).

Sounds exceeding 85 decibels can be harmful, depending on the duration and frequency of exposure. Previous research shows that workers in mines, quarries, sawmills, textile factories, printing presses, and other industries often deal with machinery that generates noise levels beyond acceptable limits (Gyamfi et al., 2016).

Noise tends to travel further in cold, dense air compared to warm air and can be intensified by atmospheric inversions (Attenborough, 2014). It can also be absorbed or blocked by topographic features or vegetation. Several studies have assessed noise levels in industrial environments, with a particular focus on mining and quarrying sites (Henry et al., 2017).

In Ghana, a study of quarry centers found that three out of five companies had average hearing threshold levels exceeding 25 decibels (Gyamfi et al., 2016). Over 25% of workers at these companies reported Noise-Induced Hearing Loss (NIHL), with the highest prevalence among workers (Gyamfi et al., 2016). The degree of hearing loss among those with thresholds above 25 decibels ranged from mild to severe, with 75% experiencing mild loss, 18% moderate, 5% moderately severe, and 2% severe loss (Debrah, 2021). This highlights the significant risk of hearing damage among quarry workers and underscores the need for effective interventions to address this issue. Other

research supports that quarry workers are exposed to noise levels that far exceed acceptable limits, increasing the risk of hearing loss (Henry et al., 2017; Josephine et al., 2019).

2.2.3.5 Health Risk of Noise Exposure

Noise-induced hearing loss (NIHL) has long been recognized as an occupational condition. Estimates suggest that 12% of the global population is at risk of hearing impairment due to noise exposure (Khandelwal & Gupta, 2023). The World Health Organisation reports that noise exposure contributes to one-third of all cases of deafness (Thai et al., 2021). NIHL can result from a single very loud sound or from continuous exposure to loud noises, and typically affects both ears when noise levels exceed 85 decibels (dB) (WHO, 2021). According to the WHO, material hearing impairment is defined as an average hearing threshold level exceeding 25 decibels in both ears (Khandelwal & Gupta, 2023).

OMS (2021) highlights that over 1.5 billion people worldwide experience some degree of hearing loss during their lifetime, with at least 430 million requiring care (Khandelwal & Gupta, 2023). Hearing loss can have significant impacts, affecting language development, psychosocial well-being, quality of life, educational achievement, and economic independence. If left unaddressed, hearing loss incurs a global cost exceeding \$980 billion annually and threatens the global goal of eradicating poverty by 2030 (WHO, 2021).

A study on quarry workers in Ghana assessed noise exposure and hearing capabilities among employees from five quarry companies (Bannerman et al., 2018). The study included employees with over six months of experience and excluded those with pre-existing hearing loss or who were not directly involved in quarrying. The sample comprised 400 quarry workers, mostly men with an average age of 41.7 years (Materu et al., 2023). The noise levels in all companies ranged from 85.5 dB to 102.7 dB, surpassing the 85 dB threshold and indicating potentially harmful exposure for workers. These findings align with Masoudzadeh et al. (2017), who found that people exposed to noise pollution had higher average disorder rates compared to those in less polluted areas. Although people may adapt to noise over time, this adaptation does not protect them from the harmful effects of noise pollution, which can lead to long-term health issues (Materu et al., 2023). Hearing loss accounts for over 35 million Disability-Adjusted Life Years (DALYs) annually and is a major component of the Global Burden of Diseases. Addressing this issue requires integrating ear and hearing care into national health care systems with a focus on people-centered approaches (Materu et al., 2023).

2.2.3.6 Work-related Health and Safety Issues in Quarrying

Every occupation carries specific risks that can lead to diseases or injuries, either suddenly or over time. These risks, known as "occupational hazards," arise from the nature or conditions of a particular job (Debrah, 2021). For instance, due to the high incidence of accidents on construction sites and during maintenance, health and safety are crucial in the construction industry (Njaka et al., 2021). Similarly, various studies in Europe have identified occupational risks faced by interventional cardiologists

(Alemayehu et al., 2020), sanitation workers (Oza et al., 2022), meat processing workers and migrant workers (Debrah, 2021).

The quarry industry presents complex challenges to occupational health and safety, with severe risks including fatal accidents, physical injuries, and work-related illnesses such as silicosis and tuberculosis from dust inhalation (Debrah, 2021). Quarry workers face higher accident rates compared to other workers, and many do not use personal protective equipment. Additionally, there are often no first aid facilities or ambulance services available on-site or nearby for injured workers (Jobin et al., 2017). Quarrying activities also significantly impact the environment, causing noise pollution, air pollution, vibrations, biodiversity loss, and habitat destruction due to rock blasting (Kolie et al., 2021).

Short-term exposure to particulate matter (PM) from air pollution can lead to acute cardiovascular issues and reduced life expectancy. Elevated PM levels have been found to negatively affect the cardiovascular health of quarry workers, leading to increased systolic and diastolic blood pressure as well as heart rate (Ottah-Umahi et al., 2020). The lungs are particularly susceptible to environmental pollutants. Despite advances in technology, workers in stone processing remain at high risk for deteriorating pulmonary function (Ottah-Umahi et al., 2020). Silica-exposed workers often have significantly lower peak expiratory flow (PEF), which correlates positively with the duration of exposure. Numerous studies indicate that exposure to stone dust adversely affects

cardiorespiratory functions, resulting in higher pulse rates and blood pressure (Debrah, 2021).

The duration of silica dust exposure is a key factor in the decline of pulmonary function: longer exposure leads to greater impairment. Significant reductions in forced vital capacity (FVC) and forced expiratory volume (FEV) are observed, with the most pronounced decreases occurring in workers with over 15 years of exposure (Debrah, 2021; Ottah-Umahi et al., 2020).

2.3 International Labour Organisation (ILO)

The International Labor Organisation (ILO) was founded in 1919 under the Treaty of Versailles, which concluded World War I. In 1946, the ILO became a specialized agency of the United Nations. Its distinctive tripartite structure ensures equal representation for workers, employers, and governments (Ottah-Umahi et al., 2020). The ILO focuses on four strategic goals: improving social protection coverage and effectiveness for everyone, and strengthening tripartism and social dialogue (Sudo, 2021).

2.3.1 ILO: Safety and Health in Mines Convention

The 1995 Safety and Health in Mines Convention (No. 176) is essential for advancing the ILO's decent work agenda and ensuring a safe future for the mining industry. This convention addresses various safety and health aspects of mining work, including inspections, specialized equipment, and protective gear for workers. It also sets standards for mine rescue operations (ILO, 98 C.E.).

The Convention is complemented by the "R164 - Occupational Safety and Health Recommendation, 1981 (No. 164)." This recommendation provides additional guidance on supervising safety and health in mines, including standards for equipment and appliances, and protocols for mine rescue and first aid. It also outlines emergency plans and procedures, as well as the rights and responsibilities of workers and their representatives (Convention et al., 2011).

2.3.2 ILO: Codes of Practice on Safety and Health in Quarrying

This code supplements the 1995 Safety and Health in Mines Convention (No.176) and its supplementary Recommendation (No. 164). It provides guidance on appropriate strategies for addressing the range of occupational safety and health risks encountered in quarrying. Exposure to excessive noise and vibration, falls from great heights and lifting heavy weights were identified as major contributors to injuries and illness (International Labour Office, 2017). It is based on the Convention's principles, including risk assessment, and addresses issues such as the interaction between large-scale and small-scale artisanal miners. It also includes a section on automated machinery, a development that has the potential to change the work performed by nearly all workers in opencast mines worldwide (ILO, 98 C.E.; International Labour Office, 2017).

2.4 Occupational Health and Safety Legislation in Ghana

Ghana's industrialization has led to an increase in the number of people exposed to physical, chemical, biological, and psychological stressors at work. The concept of occupational health and safety (OHS) in industries was conceived in Ghana long before

the Factories, Offices, and Shops Act of 1970 (Annan *et al.*, 2015). Other legal instruments have been introduced in various sectors to control employers and employees. These include but not limited to the Mining and Minerals Regulations 1970 LI 665, the Workman's Compensation Law 1987, the Ghana Health Services and Teaching Hospital Act 526 (1999) and the National Road Safety Commission Act 1999 (Act 567) (Annan *et al.*, 2015). Nonetheless, as noted by Quartey & Puplampu (2012), "these few legal provisions require significant modification to meet international requirements and standards".

Despite all of these laws, there are several gaps in the legal provisions on occupational health and safety, particularly in Ghana's informal sector Annan *et al.* (2015), therefore, Adei *et al.* (2021), asserts that, informal jobs are not only "flexible, precarious, and insecure," but they are also found in unhygienic and dangerous environments. The informal sector is frequently characterized by severe forms of workplace hazard exposure. According to estimates, two-thirds of the world's workers work in conditions that fall short of the ILO's minimum standards.

Secondly, the disparity in OHS performance is primarily due to a failure to prioritize OHS issues and the perceived burden of implementing OHS measures. It can be argued that poor implementation of OHS standards in the construction industry will result in more and more OHS incidents and accidents, which will impede the progress of many projects (Eyiah *et al.*, 2019). An enabling OHS regulation serves as the framework within

which construction firms' OHS programmes, when properly implemented, ensure the success of construction projects (Eyiah *et al.*, 2019).

Furthermore, there is a lack of specification of standards, which should serve as the yardstick against which services are to be evaluated. Although the Workmen's Compensation Law addresses compensation payable by an employer to an employee, the definition bears no relation to the level of risk to which workers are exposed. The laws do not define OHS funding mechanisms that should be used by both the government and the private sector. As a result, OHS programmes are grossly underfunded, reflecting the government's low priority (Annan *et al.*, 2015).

Ghana's government has introduced measures to promote and guarantee workers' rights but dividends accrued have so far been limited to formal sector workers. Most workers operating in the informal sector remain far from enjoying their full rights. They are either ignorant about the law or unable to secure the needed support to seek justice (Osei-Boateng & Ampratwum, 2011).

2.5. Occupational Health and Safety Approaches in Mining and Quarrying

Adoption and implementation of a national preventative OSH protocol is an important pillar of a universal OSH strategy. New technologies, globalisation, and ongoing demographic shifts have resulted in far-reaching changes in the workplace and new challenges for worker safety and health (Rantanen *et al.*, 2017). According to Zwetsloot *et al.* (2017), the zero-accident vision is a promising approach developed in industry that

has received little attention from the safety science research community. Twerefou & Tutu (2013), argues that policy-makers in the mining and quarrying industry should develop policies that are simple to implement and take into account occupational safety and health strategies. The policies should include local miners' associations and cooperatives to build capacity for effective mining regulation, with the goal of protecting natural resources and ensuring good health and safety standards (Craik *et al.*, 2017). As reported by Blair (2017), effective safety strategies include safety controls and corrective action. A corrective action is something that is done to avoid or reduce workplace risk (Blair, 2017).

Mining and quarrying leaders should also develop policy frameworks for occupational exposure limits (OEL) based on mine toxicity studies, rather than simply adopting OELs from other countries. The limits should consider the issue of mixtures to which workers may be exposed, as well as the workers' health status (Utembe & Gulumian, 2015). Managers should develop effective accident prevention interventions to improve occupational safety and health (Liu *et al.*, 2015). The conditions that cause injuries must be clearly reflected in regulatory standards, which must be communicated to workplace parties, and enforcement strategies to identify and address noncompliance must be implemented (Mapuvire *et al.*, 2022).

Understanding accident causation was a critical step in the pursuit of reducing workplace accidents and designing effective remedies. Mining executives should identify gaps in safety and health standards and work to prevent common causes of mining accidents

through training programmes (Zwetsloot *et al.*, 2017). Every mine should have a good emergency management system in place, and everyone in the company should know what to do in any given situation (Altınöz & Özmen, 2015). Finally, safety should be approached in the same way that productivity is, with the goal of continuous improvement (Mabika, 2018).

Mining companies should strengthen their risk-reduction role by properly assessing the health consequences of their projects using an integrated Environmental Impact Assessment (Viliani *et al.*, 2017). Mining industry leaders must ensure that training is developed and disseminated with various levels in mind: individual, interpersonal, organisational, and community to promote skills (Haas & Yorio, 2019). Training has the potential to support learning and behaviour change while also being consistent with feedback and development approaches (Passmore *et al.*, 2015).

2.6 Occupational Hazards

Employees can be exposed to a wide range of potentially hazardous conditions or hazards at work, according to Andel *et al.* (2015), which can lead to safety outcomes that negatively affect physical and psychological health. Although not every hazard exposure results in injury or illness, reducing hazards can be an effective way to improve safety (Andel *et al.*, 2015). Occupational hazards occur in all sectors of employment be in agriculture, construction, manufacturing and service industry. Hazards can be introduced over time as workstations and processes change. The Occupational Safety and Health Act has been enacted by Parliament in many part of the world to provide for the right of

persons to work under satisfactory, safe and healthy conditions (Nafuna, 2019). Individuals, families, and communities, as well as global citizens, are affected by occupational health issues, emphasizing the importance of occupational health (Ahmad *et al.*, 2016).

2.6.1 Types of Occupational Hazards in the Quarry Sites

Physical hazards: Working in a quarry puts a lot of physical strain on personnel, and excavation and processing work on quarry sites is regarded as a very hazardous occupation. Some of the significant physical health and safety dangers quarry workers are exposed to include working at height, operating heavy and noisy machinery, use of explosives, risk of stone or sand collapsing among many others (Ahmad *et al.*, 2016). These expose employees to unnecessary risks such as hearing loss, respiratory diseases, dermatitis, musculoskeletal injuries among others if safety practices are not followed (Andel *et al.*, 2015).

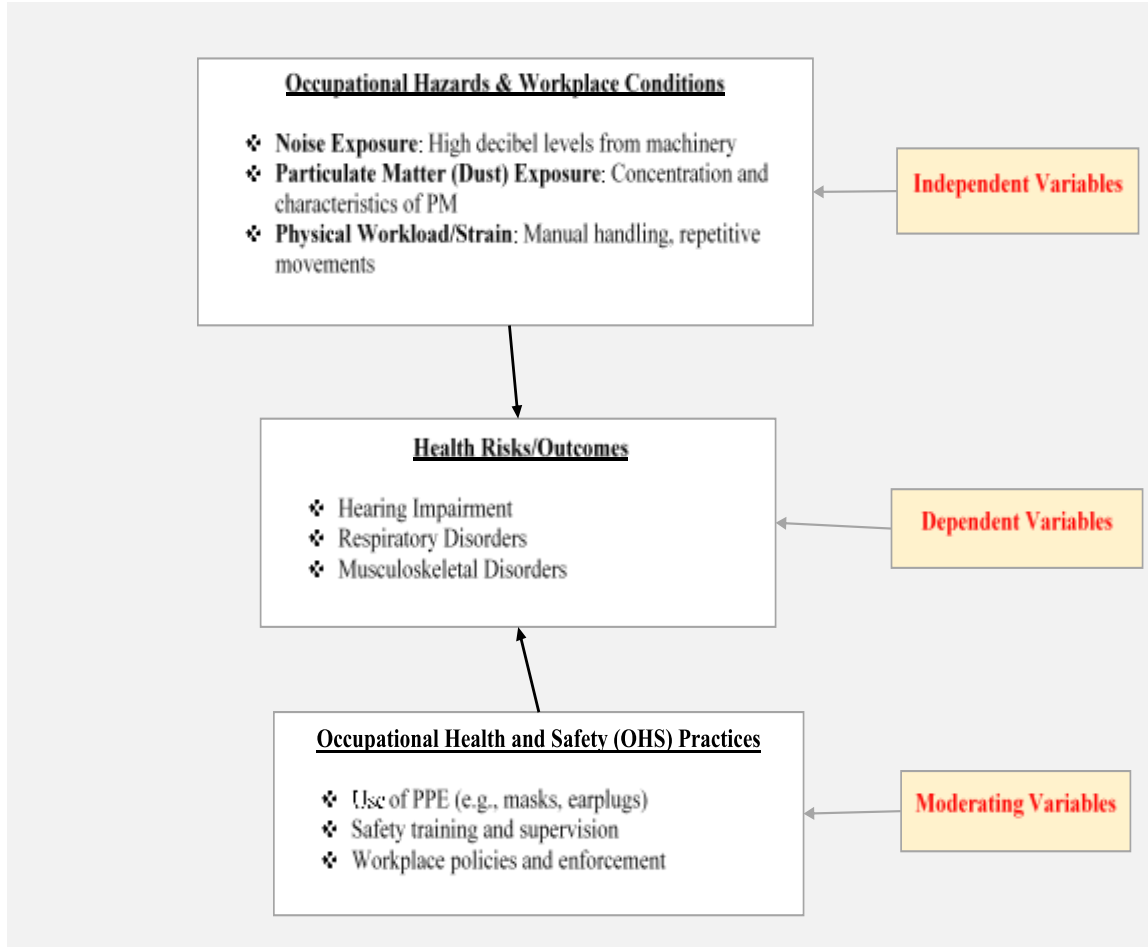
Chemical hazards: Research conducted on quarry site has revealed the natural radioactivity of uranium-238, thorium-232 and potassium-40 and their potential radiological consequences in rocks at quarry sites (Alnour *et al.*, 2012). Other gaseous risks include respiratory irritants found in diesel engine exhaust and blasting byproducts. During mine fires, CO concentrations can reach not only dangerous levels but also pose an explosive risk. Carbon monoxide (CO) and oxides of nitrogen (NO_x) are produced by diesel engines and as byproducts of blasting. These gaseous chemicals pose significant health risk to quarry workers. Pneumoconiosis and asthma are caused by inhaling dusts,

gases, metals, and their compounds (Ahmad et al., 2016). Heavy metal exposure has been linked to mid and long-term health risks such as abdominal pain and foetal illness (resulting in abortion and/or preterm labour). Adults may also experience high blood pressure, fatigue, kidney problems, and cognitive dysfunction. Chronic heavy metal exposure can also cause skin eruptions, intestinal ulcers, and various types of cancer (Awodele et al., 2014). Three new research directions for chemical protective clothing are currently being investigated (Aidani et al., 2015).

Psycho-social hazards: They are defined as "aspects of work design, organisation, and management, as well as their social and environmental context, that have the potential to cause psychological or physical harm" (Chirico et al., 2019). They result from "interactions between and among work environment, job content, work organisation, and workers' capacities, needs, culture, and personal extra-job considerations that may influence health, work performance, and job satisfaction through perceptions and experience" (Chirico et al., 2019).

Mechanical hazards are caused by relative movements of human body parts and objects such as work equipment or work objects, which result in their contact (Blunt & Balchin, 2002). Injuries, deaths, and property damage caused by electrocutions and short-circuiting, as well as fires caused by inadequately stocked combustible materials, are common in industries (Ahmad et al., 2016).

2.7 Conceptual Framework



The conceptual framework for this study illustrates the relationship between occupational hazards and health risks among quarry workers in the Gomoa East District. It posits that exposure to workplace hazards particularly noise from machinery and airborne particulate matter (dust) directly contributes to adverse health outcomes such as hearing loss, respiratory disorders, and musculoskeletal problems. However, the framework also highlights the role of occupational health and safety (OHS) practices as a moderating variable. Effective OHS measures, including the use of personal protective equipment (PPE), safety training, and enforcement of safety protocols, can potentially reduce the severity or likelihood of these health risks.

3.2 Study Design

The study employed an analytical design involving selected quarry companies in the Gomoa East District of the Central Region of Ghana to assess occupational health practices among the workers. Some of the selected quarry companies included Pilot Quarry Limited and Executive Quarry Limited.

3.3 Study Population

Gomoa East District has two (2) privately owned and operational quarries. The population of this study included all the quarry workers at the study sites. These two quarry firms had a total workforce of about 140 quarry workers. This total consists of 60 workers at the site A (Pilot Quarry Limited) and 80 workers at site B (Executive Quarry Limited). These workers however, work at different departments/Units within these companies.

3.4 Sample Size Estimation

A total of 102 quarry workers were available and consented to participate in the study. The use of the entire accessible population from these two firms was justified based on the study's localized focus, the practical constraints of accessing the entire regional quarry workforce, and the aim to obtain detailed and reliable data from the selected sites. Thus, although the regional estimate recommended a higher sample size, the 102 respondents captured from the two firms are sufficient and appropriate for the purpose and setting of this study.

3.5 Sampling Technique

A purposive sampling technique was employed to select the two quarry companies: Pilot Quarry Limited and Executive Quarry Limited as the study sites. These firms were chosen based on their size, level of operational activity, accessibility, and relevance to the study objectives within the Gomoa East District.

Within the selected quarry sites, a census sampling approach was used to include all available workers who met the inclusion criteria. This allowed for the comprehensive participation of quarry workers who were directly or indirectly involved in operational activities. Additionally, where it was not possible to reach every eligible individual due to time or availability constraints, a convenience sampling method was employed to engage workers who were present and willing to participate during the data collection period. This combined approach ensured that the study captured a broad and representative perspective of occupational health risks within the selected quarry environments.

3.5.1 Inclusion and Exclusion Criteria

All quarry workers from the selected sites were eligible to participate in the study. This included individuals directly involved in mining operations such as drilling, blasting, digging, and crushing rocks, as well as those responsible for transporting and processing aggregates. Administrative staff working within the premises of the selected quarry companies were also included, as they are part of the occupational environment and may be exposed to indirect workplace hazards.

Workers who were on leave, absent during the period of data collection, or refused to give consent were excluded from the study. Additionally, contract or casual workers not officially employed by the two quarry firms, as well as external service providers such as delivery drivers or visitors, were not included in the study sample.

3.6 Data Collection

Three main instruments were used for the collection of data.

3.6.1 Survey on Occupational Health and Safety Practices

Specific Objective one examined occupational health and safety practices among quarry workers. A structured questionnaire designed to capture the demographic characteristics of the study participants, occupational health and hazards exposures, safety practices, etc., was used to solicit data from the respondents. Other data tools included in-depth interview guide to gather further data from the occupational health and safety personnel and management.

3.6.2 Determination of Noise Levels

Specific Objective two determined noise levels at quarry work stations and general work environment. To determine noise levels, firstly, the nsrt_mk3 Sound Level Meter Data Logger was used in measuring noise. The brand of the sound level meter was obtained from the Air Quality Sensor Evaluation and Training Centre at the Department of Physics, University of Ghana. The noise meters used were calibrated before taking noise measurements using a calibrated device of 1kHz frequency and sound pressure level. The

noise meters were set at an appropriate range for the noise measurement and avoided overloads. The noise level was measured at the measurement places identified and as closely as practicable depending on the time of day that the noise was generated. Outdoor/ambient noise levels were measured at least 1.5m above floor level from any wall or other reflecting surfaces; in line with GS1222:2018 and Environment, Health, and Safety Guidelines of IFC. For all the noise level measurements, the axis of maximum sensitivity of the microphone was directed towards the noise source or upward when sound level meters were used. The equivalent noise level (L_{eq}), L_{50} , minimum (L_{min}), and maximum (L_{max}), levels were measured. The reference point of measurement used were L_{eq} (on A-weighted scale), in line with clause 5.2.4 of GS1222:2018. L_{eq}/L_{Aeq} were used to measure continuous sounds, such as road traffic noise or residential, commercial/industrial noise among others.



Figure 3.1: nsrt_mk3 Sound Level Meter Data Logger

3.6.3 Particulate Matter Concentrations Estimation

Specific Objective three sought to determine the concentration of particulate matter at work stations and general work environment. The Purple Air Classic (PA-II) Air Quality Monitor was obtained from the Air Quality Sensor Evaluation and Training Centre at the Department of Physics, University of Ghana. This was used in determining particulate matter concentrations at the quarry sites. All air sensors were located away from obstacles and buildings such that the distance between any obstacle and the inlet of the monitor was at least twice the height that the obstacle protrudes above the sampler. An unrestricted airflow in an arc of at least 270 degrees was allowed around the inlet of the monitor (O'Connor, 2018).

Air sensors were placed at a minimum height of 1.5 to 5 meters above ground level to prevent the collection of ground level dust temporarily made airborne by gusting winds (O'Connor, 2018). These sensors use fan to draw a sample of air past a laser beam. The laser beam reflects light from any fine particulate matter particles that exist in the air sample to obtain the curve of scattering light change with time. These reflection measurements from particles were used to infer the mass concentrations of $PM_{1.0}$, $PM_{2.5}$, and PM_{10} for standard indoor and outdoor atmospheric particles. The PM data for the period of study was downloaded from the SD card in the sensors.



Figure 3.2: PurpleAir Classic (PA-II) Air Quality Monitor

3.6.3.1: Operation Mechanism for PurpleAir Classic (PA-II) Air Quality Monitor.

The PurpleAir Classic (PA-II) Air Quality Monitor is used for measuring air quality, particularly fine particulate matter (PM). Below is a detailed description of its operating mechanism:

The PurpleAir PA-II uses dual laser particle counters to detect and measure particulate matter (PM). These sensors are designed to monitor both PM_{2.5} and PM₁₀ particles, which include dust, pollen, smoke, and other airborne pollutants. Inside the PA-II, each laser particle sensor has a laser beam that passes through the air drawn into the sensor chamber. As particles in the air intersect with the laser beam, they scatter the light (Milanzi, 2023). This scattering is detected by a photodetector, which converts the light signal into an electrical signal proportional to the size and concentration of the particles. The PA-II actively draws air into the sensor chambers through small intake fans. This

continuous air sampling ensures that the sensors receive a steady flow of ambient air for real-time monitoring. The PA-II is equipped with two independent particle sensors (Jacobson et al., 2021). This redundancy helps to ensure data reliability and allows for cross-verification of readings between the two sensors.

The signals generated by the sensors are processed by an onboard microcontroller. This microcontroller calculates the concentration of particulate matter in the air and converts the raw data into standard units like micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) (Jacobson et al., 2021).

The PA-II provides measurements for PM1.0, PM2.5, and PM10, covering a wide range of particle sizes relevant to human health. The PA-II connects to a Wi-Fi network, allowing it to transmit data to PurpleAir's cloud platform in real-time. Users can access this data through PurpleAir's online map, which displays air quality readings from multiple monitors in various locations. The data is available through PurpleAir's website, where users can view real-time and historical air quality data. Additionally, the PA-II allows integration with third-party applications and services for enhanced data analysis and reporting.

The PA-II does not have a built-in display but relies on its online platform for data visualization. Users can view air quality levels, trends, and comparisons over time. The device includes an LED indicator light that provides a quick visual cue of the device's operational status, such as connectivity and power (Milanzi, 2023).

While the PurpleAir PA-II is factory-calibrated, periodic checks are recommended to ensure ongoing accuracy. Users may need to recalibrate the device in environments with extreme conditions or after significant usage periods. The PA-II is designed to be low-maintenance, but keeping the sensor area clean from dust and debris is essential to maintain accurate readings (Jacobson et al., 2021).

The PA-II operates on external power and requires a standard AC outlet. It is designed for continuous operation and is typically installed outdoors, although it can also be used indoors (Milanzi, 2023). This operating mechanism allows the PurpleAir Classic (PA-II) to provide reliable, real-time air quality monitoring, making it a valuable tool for individuals, communities, and organizations concerned with air pollution and public health.

3.6.4 Health Risks Estimation

Specific Objective four, seeks to estimate health risks associated with occupational exposures to particulate matter and noise among quarry workers. Risk analysis would be conducted by assessing the health risk for short-term effect of PM_{2.5}.

Abbreviations and Their Meanings of Air Pollutants and Particles

PM_{2.5} – Particulate Matter with aerodynamic diameter less than or equal to 2.5 micrometers

PM₁₀ – Particulate Matter with aerodynamic diameter less than or equal to 10 micrometers

Health Risk Assessment Metrics

ADD	–	Average Daily Dose
FADD	–	Field Average Daily Dose
SADD	–	Safe Average Daily Dose
HQ	–	Hazard Quotient
HI	–	Health Index (Sum of Hazard Quotients)
RR	–	Relative Risk
AF	–	Attributable Fraction
ER	–	Excess Risk

Parameters in Equations

C	–	Concentration of PM (in $\mu\text{g}/\text{m}^3$)
IR	–	Inhalation Rate (in m^3/day)
BW	–	Body Weight (in kg)
X	–	Annual mean concentration of PM ($\text{PM}_{2.5}$ or PM_{10}) (in $\mu\text{g}/\text{m}^3$)
X₀	–	Background concentration of PM (in $\mu\text{g}/\text{m}^3$)
β	–	Risk function coefficient (unitless)

Noise Exposure Metrics

Dose	–	Percentage of noise exposure dose over a period (T)
Leq	–	Equivalent continuous sound level (in dB), A-weighted, over time T
Lex	–	Normalized or standardized sound level over 8 hours (in dB)
T	–	Sampling time or duration of measurement (in hours)
TWA	–	Time Weighted Average (in dB), average exposure level over 8 hours

Organizations and Guidelines

US EPA – United States Environmental Protection Agency

WHO – World Health Organization

OSHA – Occupational Safety and Health Administration

3.6.4.1 Health Risk Assessment Methodology for Short-Term Effect of PM₁₀ and PM_{2.5}

The US EPA's recommended guideline for human health risk assessment was used to evaluate the possible effects of PM_{2.5} inhalation exposure. The Hazard Quotient (HQ) and Average Daily Dose (ADD) were used to assess the non-carcinogenic health risk (Das et al., 2020).

$$\text{ADD} = (\text{C} \times \text{IR})/\text{BW}. \quad (1)$$

Where:

C signifies Concentration ($\mu\text{g}/\text{m}^3$) of PM_{2.5},

IR, Inhalation Rate ($14.9 \text{ m}^3/\text{day}$) of PM_{2.5}, and

BW, Body Weight (68 kg).

Exposures were assessed by calculating Field Average Daily Doses (FADD) using Equation (1) with the levels measured at the quarry site.

Equation (1) was also used to estimate Safe Average Daily Doses (SADD). The concentration of PM_{2.5} used for SADD calculation is the WHO guidelines ($15\mu\text{g}/\text{m}^3$) and daily average of the Ghana Standard ($35\mu\text{g}/\text{m}^3$) (Asseko, 2017).

The US EPAs recommended values for inhalation rates were used since no local data was available. Non-cancer health risks, expressed as unitless Hazard Quotients (HQ) were then calculated for each exposure using Equation (2):

$$\mathbf{HQ = FADD/SADD.} \quad (2)$$

$HI = \sum HQ$, where HI is the Health Index and HQ is the Health Quotient.

The non-carcinogenic risk (HQ) or (HI) in humans can be evaluated by the ratio of the average daily dose to the reference dose. If the $HQ \leq 1$, it exhibited no adverse health effects, while $HQ > 1$ showed likely adverse health effects (Chen et al., 2022).

According to Bodor *et al.* (2022), to determine the short-term exposure to PM_{10} , the Relative Risk (RR) for all-cause mortality were calculated if the PM_{10} concentration is higher than the background level ($10 \mu\text{g m}^{-3}$). A risk function coefficient of 0.0008 was used (Bodor et al., 2022).

$$\mathbf{RR = \exp [\beta(X - X_0)]}$$

Where:

X: Represents the annual mean concentration of PM_{10} ($\mu\text{g m}^{-3}$),

X_0 : Represents the background concentration of PM_{10} ($10 \mu\text{g m}^{-3}$), and

β : Is the risk function coefficient.

The Relative Risk associated with $PM_{2.5}$ was calculated separately for cardiopulmonary and lung cancer mortality for quarry workers over 30 years old using the equation below.

$$RR = [(X + 1)/(X_0 + 1)] \beta$$

Where:

X: Represents the annual mean concentration of PM_{2.5} ($\mu\text{g m}^{-3}$),

X₀: is the background concentration of PM_{2.5} ($3 \mu\text{g m}^{-3}$), and

β : Is the risk function coefficient. The applied β coefficients of 0.15515 and 0.23218 for the cardiopulmonary and lung cancer mortality will be used respectively.

Furthermore, using the determined Relative Risk (RR), the Attributable Fraction (AF) will be calculated as follows:

$$AF = (RR - 1)/RR$$

The calculated AF value will indicate deaths ratio from the respective disease, which could be avoided if the concentration levels are lower by $10 \mu\text{g m}^{-3}$ and $3 \mu\text{g m}^{-3}$ for PM₁₀ and PM_{2.5}, respectively (Rovira et al., 2020).

$$ER = (RR - 1)$$

The Exposure to ambient PM_{2.5} and PM₁₀ will be estimated as a population-weighted annual average at selected quarries in Gomoa East. The calculated exposure to PM will be used as input in the health impact assessment to determine the total number of premature deaths (Maji et al., 2017).

3.6.4.2 Health Risk Assessment for Exposure to Sounds

According to Baffoe et al. (2022), the formulae for calculating the noise exposure and noise dose are presented in the equation below:

$$\text{Dose} = 100 \times T/8 \times 10^{(\text{Leq}-85)/10\%}$$

$$\text{Leq} = 10 \log_{10} [(Dose/100) \times (8/T)] + 85 \text{ dB}$$

$$Lex = 10 \log_{10} (\text{Dose}/100) + 85 \text{ dB}$$

$$Lex = 10 \log_{10} (T/8) + 85 \text{ dB}$$

Where:

Dose: is a noise exposure dose (in%, acquired in T hours);

Leq: is A-weighted, sound level linearly energy averaged over T hours;

Lex: is sound exposure level,

A: weighted, sound level linearly energy averaged over 8 hours;

T: is the sampling time (in hours, of the measurement).

Time weighted average (TWA) convert the dose, D (%) to 8hr time weighted average.

For an eight-hour work shift, with the noise level constant over the entire shift, the TWA is equal to the measured sound level. The OSHA permissible limit for TWA is 85 dB.

$$\text{TWA} = 16.61 \times \log_{10} (D/100) + 85 \text{ dB}$$

3.6.5 Pre-testing

Pre-testing of the study's questionnaire was conducted in Fankyinekor within the Ga South Municipality, a location with features akin to the primary study area to administer at least 15 of questionnaires. Quarry workers in the various service categories were chosen using a random sampling procedure. Clarity, consistency, and acceptability of responses to the questions during pre-testing aided in the necessary modifications being made.

3.7 Data Analysis

All data collected from the sites were entered into SPSS Version 25 for further statistical analyses. Frequencies, percentages, means and standard deviations was used to summarize the data. The results generated from the data collected from the two sites was compared to each other to determine any differences using the Independent Samples t-test. Also, sound levels and particulate matter concentrations will be compared to the permissible limits prescribed by the Environmental Protection Agency, Ghana.

3.8 Limitation in Data Collection

This study employed an analytical design, which, while effective for assessing the relationship between occupational exposures and health outcomes at a single point in time, limits the ability to establish causality. Additionally, data collection was restricted to two operational quarry sites instead of the originally intended four, as two sites had ceased operations during the study period. This might have reduced the representativeness of the findings and the ability to generalize results across all quarries in the study area.

CHAPTER FOUR

RESULTS

4.0 Introduction

This chapter presents the results of the study. The presentation of the results was based on the specific objectives and covered the following sub-headings: Demographic Characteristics of quarry workers, Working experience and departments of participants, Occupational health and safety practices of participants, Noise levels at work place, Concentration and characteristics of particulate matter at work place and Health risk levels associated with occupational exposures to noise and particulate matter concentrations at the selected work place in the Gomoa East District.

4.1 Demographic Characteristics of Respondents

The study recruited a total of 102 quarry workers. The study showed that, 50% of the participants were between the ages of 15 and 35 years, while 20.6% were aged 46 to 64 years. All participants were male (100%). In terms of educational background, 80.4% had attained a pre-tertiary level of education, whereas 4.9% had no formal education. Regarding marital status, 47.1% of the respondents were married. With respect to their previous occupations before joining the quarry industry, 27.5% had worked as mechanics, and 11.8% had been farmers (Table 4.1).

Table 4.1: Demographic Characteristics

Demographic	Frequency (N)	Percentage (%)
Age range		
15-35 (Young people)	51	50.0
36-45 (Young adult)	30	29.4
46-64 (Older working group)	21	20.6
Gender		
Male	102	100.0
Female	0	00.0
Educational Level		
No Formal Education	5	4.9
Pre-tertiary	82	80.4
Tertiary	15	14.7
Marital Status		
Single	38	37.3
Married	48	47.1
Divorced	10	9.8
Widower	6	5.9
Previous Occupation		
Mechanics	28	27.5
Masons	19	18.6
Carpenter	24	23.5
Driver	19	18.6
Farmer	12	11.8

4.1.1 Roles and Working Experience of Participants

The result of the study showed that, most (81.4%) of the quarry workers were taken a role of site preparation, drilling and blasting, transportation and truck loading, 17.6% were crushing machine operators, most (63.7%) had worked for more than 5 years, 72.6% works for 8 hours or more per day and 27.5% had been in the quarry business for more than 10 years (Table 4.2).

Table 4.2: Role and Working experience of participants

Role/Working experience	Frequency (N)	Percentage (%)
Present Work		
Site Preparation	33	32.4
Drilling and Blasting	15	14.7
Transporting materials	15	14.7
Operating heavy machinery	13	12.7
Maintenance and Repair	6	5.9
Loading trucks	20	19.6
Types of Duties Performed		
Stone blasting	24	23.5
Crushing machine operator	18	17.6
Manual crushing	16	15.7
Collecting stone from grinding machine	19	18.6
Loading section	25	24.5
Years of Experience on the Job Role		
Less than 5 years	37	36.3
5-10 years	39	38.2
More than 10 years	26	25.5
Working Hours Per Day		
3 hours	6	5.9
4-6 hours	22	21.6
7-8 hours	36	35.3
More than 8 hours	38	37.3
Years in Quarry Business		
1-5 years	37	36.3
6-10 years	37	36.3
11-15 years	27	26.4
16-20 years	1	1.0

4.2 Occupational Health and Safety Practices among Quarry Workers

The study showed that, blasting and vehicle accidents, respiratory disease, falls, hearing loss and musculoskeletal injuries were the six common hazards participants experienced at the quarry sites. However, the most predominant were 22.5%, 21.6% and 20.6% for musculoskeletal injuries, falls and blasting accidents, respectively (Figure 4.1).

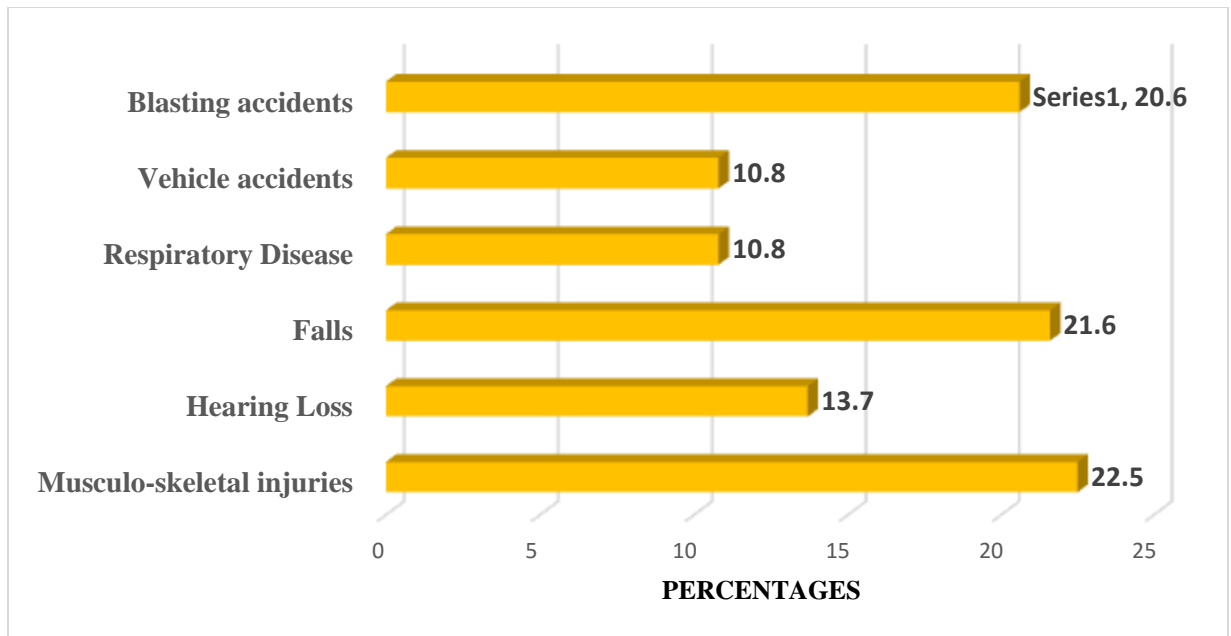


Figure 4.1: Common Hazards Experienced at Gomoa East District Quarry site

4.2.1 Measure to Prevent Accidents at Work Place

The study showed that, majority (59.8%) of the participants kept working areas free from mud and uses safety belt when climbing height to avoid slipping and falling, 21.6% periodic maintenance of tool and 14.7% used machines to handle weight to prevent objects from falling. Regular inspection was done to prevent accidental blasting, quarry workers wore helmet, masks and implemented dust collectors to protect them from dust inhalation. Noise levels were mostly monitored and hearing protections were used to reduce noise exposure (Table 4.3).

Table 4.3: Measure to prevent accidents at work place

Variable	Frequency (N)	Percentage (%)
Safety Precautions Against Falls and Slips		
Ladders are used to gain access to different heights	21	20.6
Use safety belts when climbing heights	24	23.5
Walking or working areas are kept free of mud	37	36.3
Safety shoes are used	20	19.6
Measures to Prevent Falling Objects		
Safety shoes with metal toes are always used	14	13.7
Workers are taught techniques for handling weights	3	2.9
Usage of machines to handle weights if possible	15	14.7
Periodic maintenance of tools	22	21.6
All lift wires are checked and replaced when damaged	11	10.8
Working areas with risk of fall are properly marked	13	12.7
Safety helmet use is obligatory	11	10.8
Workers always avoid staying below loads	13	12.7
Measures Against Accidental Blasts and Vibrations		
Inspect explosion risks frequently	26	25.5
Drivers' seats have suspension systems	38	37.3
Workers alternate tasks when using hand machinery	38	37.3
Measures Against Dust Inhalation		
Dust collectors are implemented in high dust areas	22	21.6
Workers have a hut to protect themselves from dust	28	27.5
Workers use masks	23	22.5
Protective glasses are used	14	13.7
Workers wear protective clothes	15	14.7
Measures Against Noise Exposure		
Noise frames are used to reduce noise from the source	19	18.6
Noise levels are regularly monitored	46	45.1
Hearing protection is available	37	36.3

4.2.2 Frequency of PPE Usage at Work Place

The study showed that, the most common reasons participants used PPEs were to avoid sun and heat exposure, enhance visibility, and protect their ears. As presented in Table 4.4, the main reasons participants sometimes did not use all the required PPEs included discomfort while wearing them and the inability to afford all the necessary PPEs, as the quarries did not provide a complete set (Figure 4.2). The study also revealed that although all participants used PPEs, a significant proportion almost half reported using face masks and eye goggles consistently. However, only a few participants used helmets (34.3%), earplugs (24.5%), hand gloves (23.5%), and wellington boots (19.6%) all the time (Table 4.4).

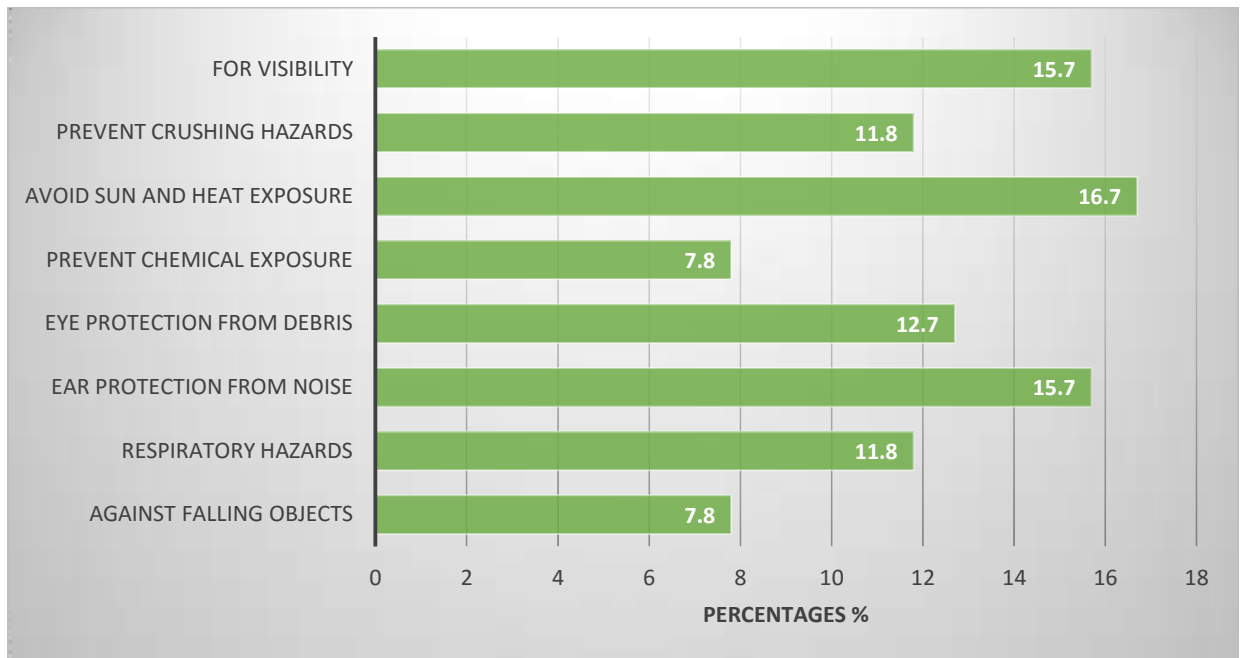


Figure 4.2: Reasons for using PPE's at the Quarry Sites

Table 4.4: Frequency of PPE usage at work place

Variable	Frequency (N)	Percentage (%)
Informed to Use PPE		
Yes	102	100.0
No	0	0
Face Mask Use		
All the time	43	42.2
Sometimes	48	47.1
Not necessary	11	10.8
Head cover/Helmet Use		
All the time	35	34.3
Sometimes	53	52.0
Not necessary	14	13.7
Eye Goggles Use		
All the time	41	40.2
Sometimes	49	48.0
Not necessary	12	11.8
Ear Plugs Use		
All the time	25	24.5
Sometimes	40	39.2
Not necessary	37	36.3
Hand Gloves Use		
All the time	24	23.5
Sometimes	56	54.9
Not necessary	22	21.6
Wellington Boots Use		
All the time	20	19.6
Sometimes	50	49.0
Not necessary	32	31.4
Reasons for Not Using all required PPE at all time		
Could not afford to buy all	22	21.6
Some PPE not provided	20	19.6
Won't injure me because I am careful	19	18.6
Feel uncomfortable when wearing some PPE	27	26.5
Some PPE not necessary	14	13.7

4.3 Noise Levels at Work Place

The study showed that, 76% of the noise produced in the quarries was continuous, while 24% was intermittent. Figure 4.4 shows that the three most common sources of noise exposure were conveyor belts (19.6%), drilling rigs (17.6%), and trucks and haulage

vehicles (16.7%) (Figure 4.3). In Table 4.5, noise levels at Executive Quarry and Pilot Quarry were measured. At both sites, noise measurements at the crusher area recorded daily maximum LAeq (equivalent continuous noise level) values ranging from 79.68 to 86.20 dBA over a 48-hour period, with a minimum value of 38.65 dBA and a maximum of 86.20 dBA. Additionally, noise measurements at the security area recorded daily maximum LAeq values ranging from 56.84 to 77.12 dBA over 48 hours, with a minimum value of 26.25 dBA and a maximum of 77.12 dBA. In Figure 4.5, although noise levels at the crusher area were generally higher than those at the security post, they occasionally overlapped or were slightly higher at specific points. However, Figure 4.6 shows that noise levels at the crusher area were significantly higher than those at the security post.

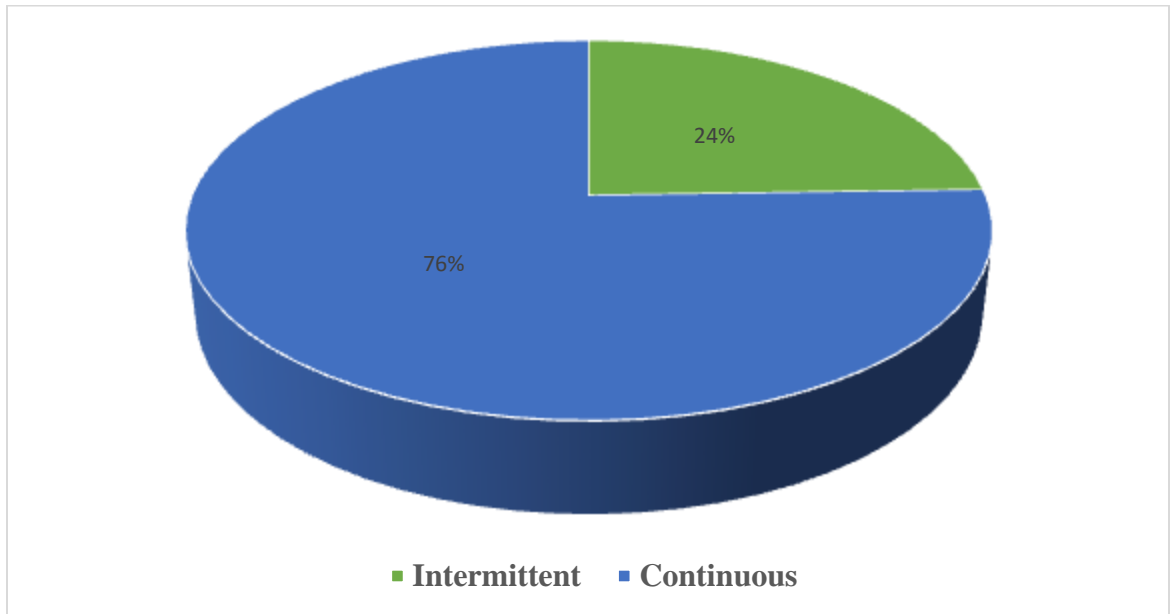


Figure 4.3: Types of Noise Exposure

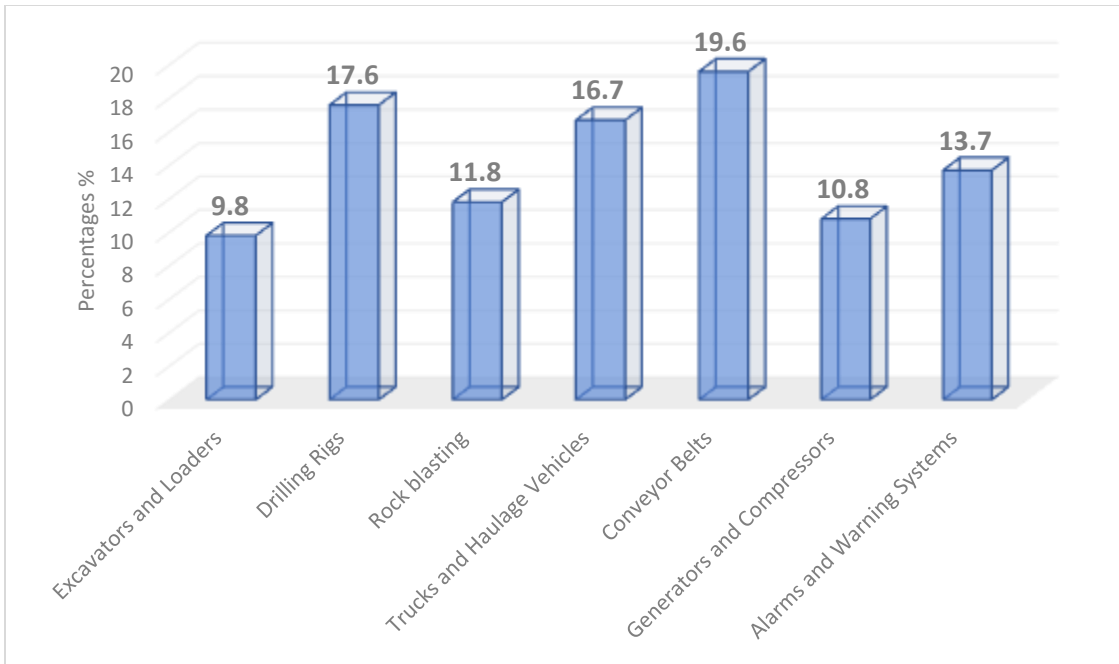


Figure 4.4: Sources of Noise Exposure at Quarry site

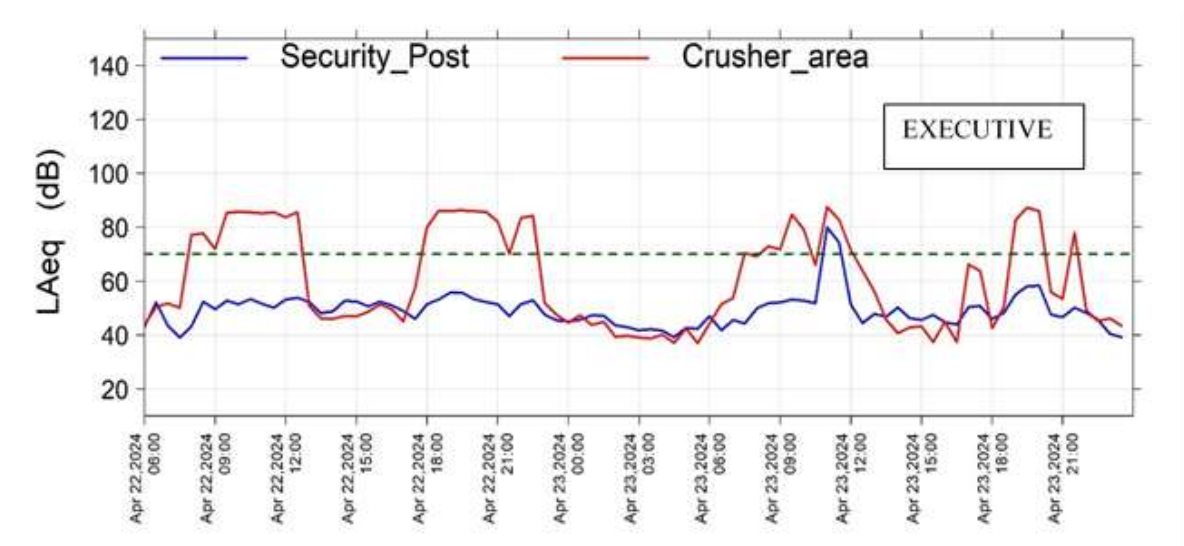


Figure 4.5: Noise Levels at Executive Quarry Comparing Crusher Area and Security Post

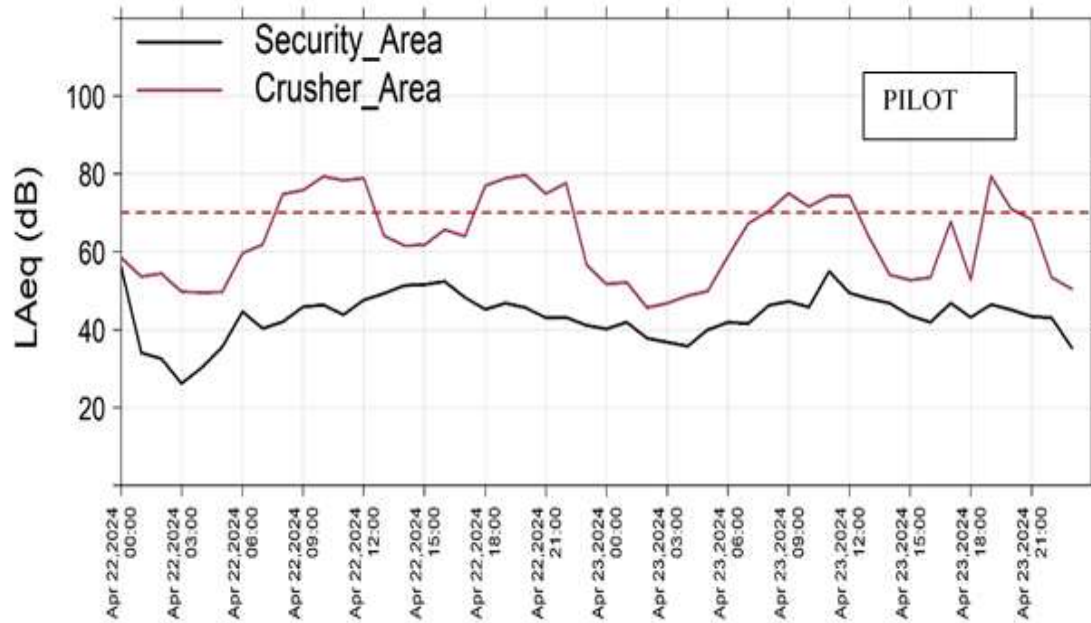


Figure 4.6: Noise Levels at Pilot Quarry Comparing Crusher and Security Area

Table 4.5: Noise Level at both Executive and pilot Quarry

Executive	mean	sd	Min	Max	P-value
Crusher area	58.98	16.98	38.65	86.20	0.023
Security Post	47.67	7.69	27.95	77.12	
Pilot					
Crusher Area	63.33	10.98	45.62	79.68	0.011
Security Area	43.47	6.05	26.25	56.84	

Note: SD= Standard deviation, min= Minimum, Max= Maximum

4.4 Assessment of Particulate Matter (PM)

The study showed that, the daily PM_{2.5} levels ranged from 36.15 to 43.37 μg/m³ at crusher area and 16.56 to 18.79 μg/m³ at security post at Executive quarry. PM levels at Pilot quarry ranged from 31.28 to 33.58 μg/m³ at the crusher area whereas levels at the security post ranged from 29.26 to 30.05 μg/m³. The daily mean PM_{2.5} recorded at Executive quarry were 39.76 ± 5.10 at the crusher area and 17.68 ± 1.58 μg/m³ at security

post. Mean daily levels from the other quarry were 32.43 ± 1.62 at the crusher area and $29.67 \pm 0.56 \mu\text{g}/\text{m}^3$ at security post. One-way Analysis of Variance revealed that there was no statistically significant difference in $\text{PM}_{2.5}$ levels from crusher areas of both quarry sites. However, levels of $\text{PM}_{2.5}$ recorded at the security post statistically differ between both quarry sites (Table 4.6 to 4.7). $\text{PM}_{2.5}$ concentrations typically showed an increasing trend starting from early morning hours, peaking around midday and decline towards late afternoon. However, $\text{PM}_{2.5}$ levels exhibited a resurgence in the afternoon to evening hours (Figure 4.7 and 4.8).

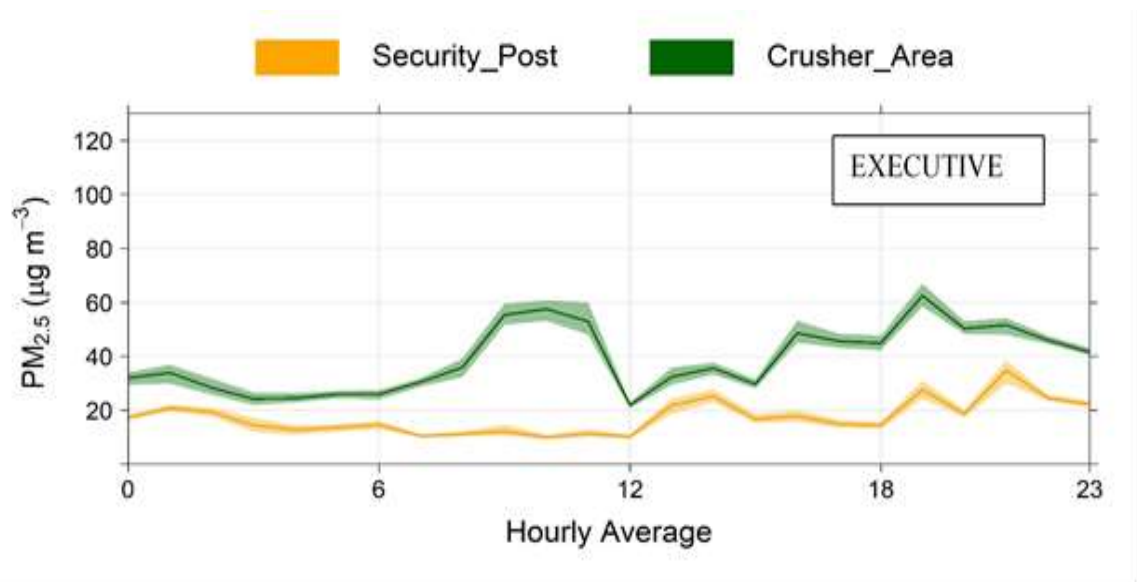


Figure 4.7: Levels of Particulate Matter at the Executive Quarry

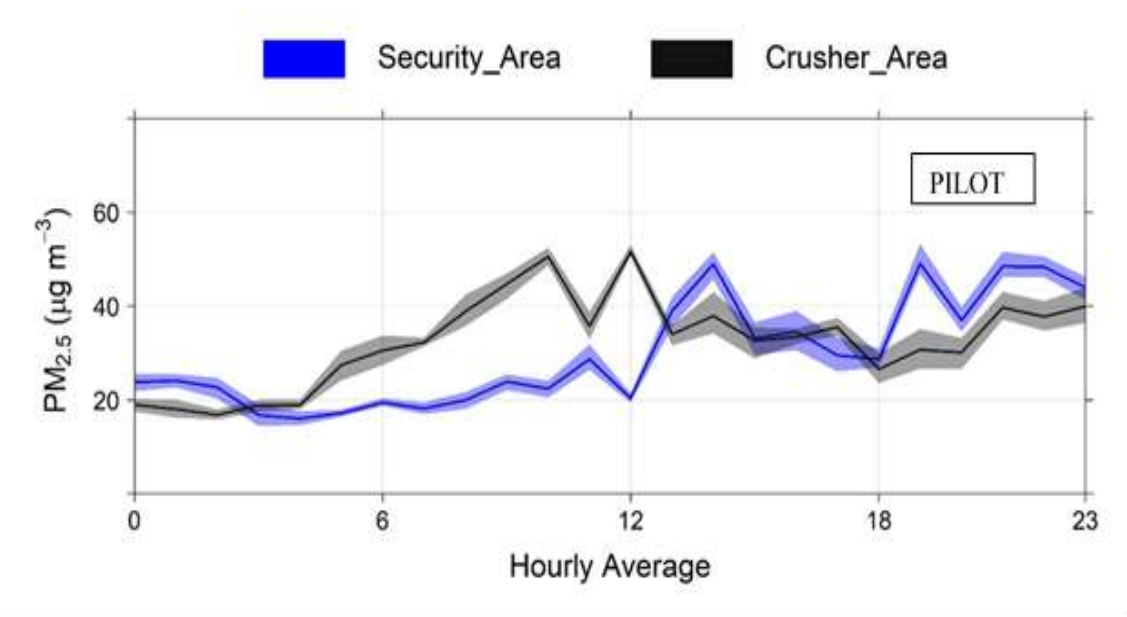


Figure 4.8: Levels of Particulate Matter at the Pilot Quarry

Table 4.6: Ambient Particulate Matter (PM)

Executive Quarry	mean	Sd	Min	Max	P-value
Crusher Area	39.76	5.10	36.15	43.37	0.041
Security Post	17.67	1.58	16.56	18.79	
Pilot Quarry					
Crusher Area	32.43	1.62	31.28	33.58	0.039
Security Area	29.67	0.56	29.26	30.05	

Note: SD= Standard deviation, min= Minimum, Max= Maximum

Table 4.7: Comparative analysis of PM levels at various quarry sites

ANOVA for Crusher Area						
Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	92.36	1	92.36	0.40	0.53	4.05
Within Groups	10657.93	46	231.70			
Total	10750.29	47				
ANOVA for Security Post						
Source of Variation	SS	Df	MS	F	P-value	F crit
Between Groups	1842.319	1	1842.32	21.95	0.003	4.059
Within Groups	3861.286	46	83.94			
Total	5703.604	47				

4.5 Health Risks associated with Noise Exposure and Particulate Matter in Quarry

In **Figure 4.9**, common signs and symptoms includes body pain, fatigue, hemoptysis, hearing loss, etc. that may be health risk or health conditions linked to noise and particulate matter exposure.

4.5.1 Health Risks Associated with Noise

The study showed that, noise level range from 56.78 to 74.86 dBA at both quarries and areas, less than the Permissible Exposure Limit (PEL) set by OSHA for an 8-hour TWA level of 85 dBA. Prolonged exposure to such high noise levels poses two main health risks. In this study, Time Weighted Average (TWA) convert the Dose (D) (%) to 8-hour time weighted average. For an eight-hour work shift, with the noise level constant over the entire shift, the TWA is equal to the measured sound level. The OSHA permissible limit for TWA is 85 dBA (Table 4.8).

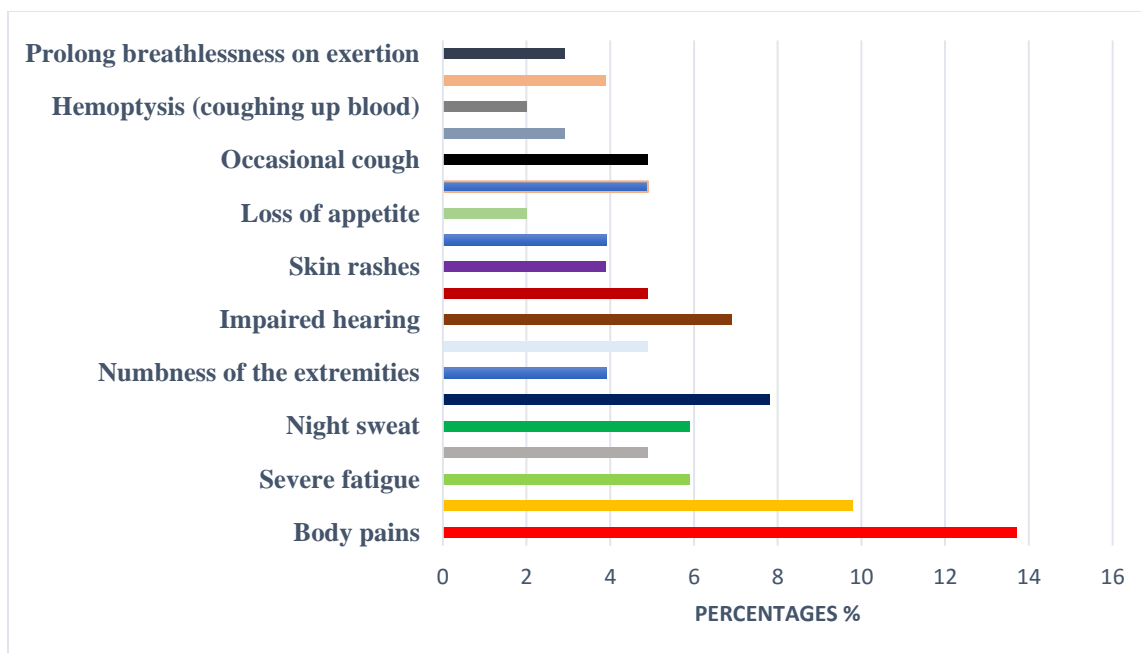


Figure 4.9: Common Signs and Symptoms among Quarry Workers

Table 4.8: Noise Risk Assessment

Noise parameters	Pilot Quarry		Executive Quarry	
	Security area	Crusher Area	Security area	Crusher Area
Dose (%)	1.0	10.94	1.1	10.94
TWA	74.86	56.78	57.47	74.04

Note: TWA= Time Weighted Average

4.5.2 Health Risk associated with Particulate Matter

In this study, the average concentrations of PM₁₀ and PM_{2.5} were measured at 150 µg/m³ and 80 µg/m³, respectively. Using the Hazard Quotient (HQ) method based on WHO guidelines (PM₁₀: 50 µg/m³, PM_{2.5}: 25 µg/m³), in **Table 4.9**, the calculated HQ values were 3 for PM₁₀ and 3.2 for PM_{2.5}, indicating a significant health risk due to elevated particulate matter levels.

Table 4.9: Measurement of Health Risk associated with PM

PM₁₀	HQPM₁₀	HQ (PM₁₀)
PM ₁₀ : 150 µg/m ³	HQPM ₁₀ = $\frac{150 \text{ µg/m}^3}{50 \text{ µg/m}^3}$	3
PM_{2.5}	HQPM_{2.5}	HQ (PM_{2.5})
PM _{2.5} : 80 µg/m ³	HQPM _{2.5} = $\frac{80 \text{ µg/m}^3}{25 \text{ µg/m}^3}$	3.2

Note:

$$\text{HQ} = \frac{\text{Exposure Concentration}}{\text{Reference Concentration}}$$

Given WHO Reference Concentrations: PM₁₀: 50 µg/m³ and PM_{2.5}: 25 µg/m³

HQ > 1 indicates significant health risk

CHAPTER FIVE

DISCUSSION

5.0 Introduction

The study aimed to assess occupational hazards and health risk among workers in selected quarry companies in the Gomoa East District, Ghana. The key findings of the specific objectives are discussed in these thematic areas: Occupational health and safety practices of participants; Noise levels at work place; Concentration and characteristics of particulate matter at work place and Health risk levels associated with occupational exposures to noise and particulate matter concentrations at work place in the study area.

The tough nature of quarry works exposes workers to danger and health risks. Quarry workers deal with loud noise, constant vibration, and lots of dust, which can lead to auditory impairment, lung diseases, and muscle and joint pain. Working with chemicals and heavy machinery, along with the physical strain of the job, adds to these risks. On top of that, the chance of accidents like falls, slips, and trips, as well as the stress of the job, makes their work environment even more hazardous. To protect these workers, it's crucial to have regular health check-ups, proper protective gear, and strong safety protocols in place.

5.1 Occupational Health and Safety Practices among Quarry Workers

5.1.1 Measure to Prevent Accidents/Hazard at Work Place

This current study revealed six common hazards among quarry work such as blasting, vehicle accidents, respiratory disease, falls, hearing loss and musculoskeletal injuries. However, the most prevalent were musculoskeletal injuries, falls and blasting. This study

confirms a study in Egypt that reported that one of the most common health hazard among quarry workers was musculoskeletal injuries. However, this study disagree with a study in Kenya that reported the most known hazard among quarry workers to be manual handling resulting in waist, back or shoulder pain (Josephine et al., 2019). What could have accounted for the disparities in occupational health hazards from the different quarries is not well defined. However, it is suspected that differences in access to all required PPEs, the resource of the quarry company and the geographical area of the quarry company (Labour, 2017). Also, the similarities in the studies could be attributed to standards and universality of nature of quarry work, quarry industry, regardless of location, tends to follow similar safety practices and protocols (Fold et al., 2018). Musculoskeletal injuries include back injuries caused by lifting heavy loads, repetitive bending, and twisting motions; shoulder injuries caused by overhead lifting, repetitive arm movements, and carrying heavy loads; hand and wrist injuries caused by repetitive use of hand tools, vibration from machinery, and awkward hand positions; knee injuries caused by prolonged kneeling, heavy lifting, and uneven surfaces; and foot and ankle injuries caused by slips, trips, falls, and carrying heavy loads.

This study revealed that majority of the quarry workers clean working areas to keep it free from mud, uses safety belt when climbing height, regularly maintain working tools and uses machines to carry heavy loads to prevent slipping and falling. This is similar to a several studies that indicated the cleaning of working area, use of machines and safety belt to prevent slipping and falling in the quarry works (Duarte et al., 2021; Rafindadi et al., 2022; Sherrigton, 2020). This study suggest that quarry workers are aware of and

actively implement safety measures to minimize risks associated with their work environment. Cleaning working areas to remove mud helps prevent slips and falls, which are common hazards in such settings (Gilkey, 2021; Sherrigton, 2020). The use of safety belts when climbing indicates an understanding of the risks associated with working at heights and the importance of fall prevention. Regular maintenance of tools suggests a proactive approach to preventing equipment-related accidents (Yadav et al., 2022). Using machines to carry heavy loads shows an effort to reduce the risk of musculoskeletal injuries and accidents caused by manual handling of heavy objects.

This study reported that most participants undertake regular inspection to prevent accidental blasting, quarry workers wear hats, masks and implement dust collectors to protect them from dust inhalation. Noise levels are mostly monitored and hearing protections are used to reduce noise exposure. This study is similar to several other studies (Ahmed et al., 2022; Campbell, 2022; Chen et al., 2020; Irizarry-Colon, 2023). This study suggests that quarry workers are highly conscious of the specific risks associated with their work environment and are taking proactive steps to mitigate them. Regular inspections to prevent accidental blasting indicate a strong focus on preventing catastrophic events that can cause severe injury or death. The use of hats, masks, and dust collectors shows an understanding of the long-term health risks associated with dust inhalation, such as respiratory diseases and silicosis. Monitoring noise levels and using hearing protection demonstrate awareness of the risks of noise-induced hearing loss and a commitment to preserving hearing health (Wang et al., 2020).

5.1.2 Frequency of PPE Usage at Work Place

This study discovered that all the participants used PPE's, a significance proportion (almost half of the participants) used face mask and eye goggles all the time, however, few of the participants used helmet, ear plugs, hand gloves, and wellington boots all the time. This suggest that, despite the high-risk nature of quarry work, a significant proportion of respondents reported minimal access to essential PPE, such as helmets, ear plugs, gloves, and wellington boots. This lack of PPE is particularly concerning given the potential for serious injuries and long-term health issues. This is consistent with other studies in Ghana and Egypt that reported that most quarry workers did not wear PPE at work (Ahadzi et al., 2020; Fouad Melika & Gomaa Mohamed Amer, 2020). Studies have consistently highlighted significant deficiencies in health and safety practices among quarry workers, including inadequate provision and utilization of personal protective equipment (PPE), absence of on-site emergency medical services, and limited adherence to established safety protocols (Lohe & Ghosh, 2022; Jobin et al., 2017; Eyiah et al., 2019; Blair, 2017; Zwetsloot et al., 2017). These issues are critical as they directly impact the safety and well-being of workers operating in inherently hazardous environments.

This current study revealed that, the most common reasons participants use PPE's were to avoid sun and heat exposure, for clear visibility, and to protect the ears. This is fairly similar to several studies that claimed that some quarry workers wear PPE to minimize exposure to hazards that can cause injury (Nganchi & Psychology, 2024; Okorie et al., 2023).

The participants use PPEs to avoid sun and heat exposure suggest that the work environment involves significant exposure to sunlight and high temperatures, which can lead to heat stress, sunburn, and other heat-related illnesses. PPE such as hats, sunscreen, and cooling garments are likely used to protect against these conditions. The use of PPE for clear visibility suggests that the work environment may have poor lighting, dust, or other visual obstructions, necessitating the use of protective eyewear or face mask to maintain clear vision and prevent eye injuries. Also the use of PPE to protect the ears indicates that the work environment has high noise levels, making hearing protection essential to prevent noise-induced hearing loss and other auditory issues.

This study reported that, the major reasons why participants at some times do not use all required PPE's were due to not feeling comfortable when wearing it, they could not afford to buy all PPE's since the quarries do not provide all. This study agrees with other studies that indicated that most quarry workers do not wear PPE due to unavailability of the required PPEs (Fouad Melika & Gomaa Mohamed Amer, 2020; Rr Dian et al., 2020). This suggest that to reduce injuries at the quarry sites, the quarry companies should make all PPEs available and access to all quarry workers to encourage them to wear to reduce any accident and injuries at the working sites.

Regular safety drills, safety audits, and routine checks of safety equipment were either infrequent or non-existent. This lack of adherence not only increases the likelihood of accidents but also reflects a broader issue of management and regulatory oversight in ensuring workplace safety. Regulatory bodies need to enforce strict compliance with

occupational health and safety (OHS) standards through regular inspections and stringent penalties for non-compliance (Zwetsloot et al., 2017). Without such enforcement, the implementation of safety measures remains superficial, leaving workers at continued risk. Addressing these deficiencies requires a multifaceted approach, including better provision and training in the use of PPE, the establishment of on-site medical facilities, and rigorous adherence to safety protocols. Enhancing occupational health and safety practices is essential for protecting the health and well-being of quarry workers and ensuring a safer working environment.

5.2 Noise Levels at Work Place

This study revealed that continuous noise was the most prevalent in the quarry companies in the study area, mostly produce from conveyor belt, drilling rigs and trucks, and haulage vehicles. This is similar to several studies that reported continuous noise from conveyor belt and heavy vehicles (Azman et al., 2022; Degan et al., 2020). Continuous exposure to high levels of noise can lead to noise-induced hearing loss, increased stress levels, fatigue, and other health issues such as hypertension. Prolonged exposure without adequate protection can result in permanent hearing damage.

This study reported that noise measurement at the Crusher area recorded a daily max LAeq (equivalent continuous noise level) value ranged from 79.68 to 86.20 dBA for 48 hours with a minimum value of 38.65 dBA and a maximum value of 86.20 dBA. Also, noise measurement at the Security area recorded a daily max LAeq value ranged from 56.84 to 77.12 dB(A) for 48 hours with a minimum value of 26.25 dBA and a maximum

value of 77.12 dBA. Similar study by Gyamfi et al., (2016) reported the range of 85 to 103 dBA at some selected quarry sites in Ghana (Gyamfi et al., 2016). Contrary to this study, stone quarry in Tanzania reported an average noise level at quarry site to be 81 dBA (Materu et al., 2023). A study reported the highest range of noise level in quarry sites to be 87 to 117 dBA as against the permissible exposure level of 85.00dB (ORIOLOWO, 2023). A study reported the Auditory Injury Threshold to be 75-78 dBA and a true safe noise level to be 60 dBA or lower (Aliakbaryhosseinabadi et al., 2023). This indicate that the noise levels at both areas are quite high, considering that normal conversation typically occurs at around 60 dBA (Benítez-Barrera et al., 2020). This suggest that, it is unsafe to work at these quarry sites without wearing ear protective device. This is because prolonged exposure to noise levels above 85 dBA can lead to hearing impairment (Fink & Mayes, 2021), indicating a risk for workers in mostly the Crusher area.

This suggest a need for strict adherence to health and safety regulations to protect workers from noise-induced hearing loss. Employers may need to implement hearing conservation programmes, provide personal protective equipment (PPE) like earplugs or earmuffs, and ensure regular monitoring of noise levels. Beyond occupational health, the high noise levels can also affect the surrounding environment and communities. Measures might need to be taken to mitigate noise pollution, such as establishing buffer zones, implementing noise abatement procedures, or conducting further studies to assess the impact on local wildlife and residents.

This current study discovered that noise level at the crusher area were though higher than that at the security post, but some point intertwines or slightly higher, whereas, noise level is far higher at the crusher area than the security post. This suggests that the crusher area, due to its nature of activities, produces more noise than the security post. This is expected because crusher operations involve heavy machinery and material processing, which are typically noisy. The occasional overlap or slight increase in noise levels at the security post might be due to sporadic noise events or environmental factors such as wind direction, proximity to other noise sources, or temporary activities that generate noise at the security post.

The study indicated high levels of noise levels at the Crusher area above the Ghana Standard prescribed limit of 70 dB during the period of operation. This implies that workers in the Crusher Area are consistently exposed to higher noise levels than those stationed at the Security Post. Such exposure highlights the potential risk of noise-induced hearing loss and other health impacts among workers in operational zones with elevated noise levels.

Generally, the noise measurements taken at the factory during both day and night periods were generally compliant with the Ghanaian standard GS 1222:2018 for industrial settings. This compliance underscores the effectiveness of existing noise control measures implemented within the quarry site. However, noise levels at the Crusher Area indicated occasional spikes above the Ghana Standard's prescribed limit of 70 dB(A) during operational hours (8 am – 10 pm). Such spikes highlight areas of potential concern

where further mitigation strategies may be necessary to consistently maintain compliance and safeguard the health and well-being of workers exposed to higher noise levels.

5.3 Assessment of Particulate Matter (PM)

This current study points out the daily PM_{2.5} levels ranged from 36.15 to 43.37 µg/m³ at crusher area and 16.56 to 18.79 µg/m³ at security post at Executive quarry. PM levels at Pilot quarry ranged from 31.28 to 33.58 µg/m³ at the crusher area whereas levels at the security post ranged from 29.26 to 30.05 µg/m³. The daily mean PM_{2.5} recorded at Executive quarry were 39.76 ± 5.10 at the crusher area and 17.68 ± 1.58 µg/m³ at security post. Mean daily levels from the other quarry were 32.43 ± 1.62 at the crusher area and 29.67 ± 0.56 µg/m³ at security post. Contrary, a study in Tanzania recorded PM level range 8 to 17 µg/m³ at a stone quarry site, slightly closer to the WHO permissible limit (Materu et al., 2023).

For all the quarries in the study, both crusher and security post sites recorded daily PM levels higher than the WHO guideline (15 µg/m³) (WHO, 2005). Daily PM_{2.5} levels at the crusher area and security area were within the daily limit prescribed by the Ghana standard (35 µg/m³). PM levels at crusher area was higher than levels at security area.

Therefore, workers near the crusher area could be exposed to higher levels of PM_{2.5} than workers near the security post. This could be an indication of high dust induced risk associated with workers at the crusher areas in quarry sites than workers at the security post. At executive quarry, PM_{2.5} levels at crusher area was twice as high as PM levels at security post. A similar comparison done at construction sites revealed that, workers on

construction fields are exposed to higher levels of PM_{2.5} than people around construction site (Mitra et al., 2022).

This current study identified no statistically significant difference in PM_{2.5} levels from crusher areas of both quarry sites. However, levels of PM_{2.5} recorded at the security post statistically differ between both quarry sites. This study discloses that PM_{2.5} concentrations typically increasing trend starting from early morning hours, peaking around midday and decline towards late afternoon. However, PM_{2.5} levels exhibited a resurgence in the afternoon to evening hours. The elevated PM_{2.5} concentration at the security area compared to the crusher area a few hours after 12 noon can be attributed to a combination of operational, environmental, and meteorological factors.

Firstly, during midday and into the early afternoon, atmospheric mixing height increases due to solar radiation, enhancing vertical dispersion of pollutants. However, as the afternoon progresses, the mixing height begins to decrease, leading to a trapping of airborne particles closer to the ground, particularly in areas where there is less mechanical dispersion like the security zone, which is more static compared to the crusher area that may have forced ventilation or active mechanical dispersion due to machinery.

Secondly, the crusher area often experiences intense activity earlier in the day, during which most particulate matter is generated. By early afternoon, the crushing operations may either reduce or stabilize, leading to lower emissions. In contrast, the security area,

often located near entrances or high-traffic zones, may begin to see increased vehicle movement (e.g., trucks and machinery returning from off-site deliveries or internal transfers), raising localized PM levels.

Additionally, wind direction and speed change during the day. If the wind shifts to carry dust and fine particles from the active zones (e.g., the crushing area or haul roads) towards the security area, this can cause a secondary peak in PM_{2.5} concentrations at that location, especially when combined with the resuspension of settled dust due to vehicular activity in the afternoon.

Lastly, the resurgence in PM_{2.5} levels in the afternoon to evening hours, as noted in the study, supports the likelihood of cumulative dust accumulation in non-operational zones, such as the security area, where movement continues but dust suppression may not be actively maintained.

This could also be attributed to the distance between the quarry processing area and security post. Other factors could result from the number of vehicles moving in and out of the site as well as other activities close to the site. PM_{2.5} concentrations typically showed an increasing trend starting from early morning hours, peaking around midday. This pattern aligns with intensified operational activities during these times, including increased crusher operations and vehicular movements within the quarry environment. The subsequent decline in PM_{2.5} levels towards late afternoon may be attributed to reduced activities or improved dispersion of particulate matter. However, PM_{2.5} levels

exhibited a resurgence in the afternoon to evening hours, suggesting potential influences from renewed operational activities or atmospheric conditions such as temperature inversions or wind patterns. These temporal variations underscore the dynamic nature of airborne particulate matter in quarry environments and emphasize the need for continuous monitoring and adaptive management strategies to mitigate exposure risks effectively throughout the day.

This disparity highlights the need for targeted interventions and control measures to reduce exposure levels, particularly in high-risk areas like the Crusher Area where workers face heightened health risks from prolonged exposure to PM_{2.5}.

5.4 Health Risks Associated with Noise Exposure and Particulate Matter in Quarry

The study uncovered common signs and symptoms which included body pain, fatigue, hemoptysis, hearing loss, etc that might be health risk or health conditions linked to noise and particulate matter exposure. The findings suggest that individuals exposed to higher levels of noise and particulate matter are at an increased risk of experiencing adverse health effects. The presence of body pain and fatigue might indicate systemic inflammation or stress responses due to chronic exposure. Hemoptysis points to potential respiratory issues, possibly due to inhalation of harmful particles. Hearing loss is directly linked to noise exposure, reflecting damage to auditory structures from sustained high decibel levels.

This study disclosed noise level range from 56.78 to 74.86 dBA at both quarries and areas, less than the Permissible Exposure Limit (PEL) set by OSHA for an 8-hour TWA level of 85 dBA. Prolonged exposure to such high noise levels poses two main health risks. In this study, Time Weighted Average (TWA) convert the Dose (D) (%) to 8-hour time weighted average. For an eight-hour work shift, with the noise level constant over the entire shift, the TWA is equal to the measured sound level. The OSHA permissible limit for TWA is 85 dBA. Workers exposed to noise levels exceeding 85 dB without adequate hearing protection are at significant risk of developing NIHL (OSHA, n.d.). Chronic exposure to excessive noise can also lead to increased stress levels, hypertension, and other cardiovascular problems among workers. These health effects highlight the need for effective noise control measures and comprehensive hearing conservation programmes in quarrying operations.

In this study, the average concentrations of PM₁₀ and PM_{2.5} were measured at 150 µg/m³ and 80 µg/m³, respectively, given the calculated Hazard Quotient (HQ) value greater than 1, indicating a significant health risk due to elevated particulate matter levels. Particulate matter, particularly PM₁₀ and PM_{2.5}, poses a substantial risk of respiratory diseases among quarry workers. PM can penetrate deep into the lungs, causing inflammation and leading to conditions such as silicosis, Chronic Obstructive Pulmonary Disease (COPD), and asthma. These diseases are debilitating and can severely impact the quality of life of affected individuals (Nyarubeli et al., 2020).

In addition to respiratory issues, high concentrations of particulate matter are associated with increased cardiovascular morbidity. Fine particles can enter the bloodstream, causing systemic inflammation and contributing to the development of heart diseases. This underscores the broader health impacts of PM exposure beyond respiratory health.

CHAPTER SIX

SUMMARY, LIMITATION, CONCLUSION, AND RECOMMENDATIONS

6.0 Introduction

This chapter presents a summary of the major findings of the study which assessed occupational hazards and health risk among workers in selected quarry companies in the Gomoa East District, Ghana. The chapter includes a summary of the research findings, study limitations, conclusions from the results obtained, and recommendations for further studies.

6.1 Summary of the Key Findings

The study focused on male quarry workers aged 18 to 35, with 80.4% having pre-tertiary education and 4.9% no formal education. The majority (81.4%) were involved in site preparation, drilling, blasting, transportation, and truck loading. Predominant health hazards included musculoskeletal injuries, falls, and blasting accidents. Most participants (59.8%) kept working areas clean and used safety belts when climbing to prevent falls; 21.6% performed periodic maintenance, and 14.7% used machines for heavy lifting. All participants used PPE, with nearly half consistently using face masks and goggles. Fewer regularly used helmets (34.3%), earplugs (24.5%), gloves (23.5%), and wellington boots (19.6%). Key noise sources were conveyor belts (19.6%), drilling rigs (17.6%), and trucks (16.7%). Noise levels were higher at the crusher area than the security post but below OSHA's 85 dBA limit. PM_{2.5} levels at Executive quarry ranged from 36.15 to

43.37 $\mu\text{g}/\text{m}^3$ at the crusher area and 16.56 to 18.79 $\mu\text{g}/\text{m}^3$ at the security post. At Pilot quarry, PM_{2.5} levels ranged from 31.28 to 33.58 $\mu\text{g}/\text{m}^3$ at the crusher and 29.26 to 30.05 $\mu\text{g}/\text{m}^3$ at the security post. Average PM₁₀ and PM_{2.5} concentrations were 150 $\mu\text{g}/\text{m}^3$ and 80 $\mu\text{g}/\text{m}^3$, respectively, indicating significant health risks with Hazard Quotient values of 3 for PM₁₀ and 3.2 for PM_{2.5}.

6.2 Study Limitation

The study was conducted within the two quarry companies in the Gomoa East District. Data collection for the study was limited to the internal environments of the companies and was not extended to include neighboring communities. The conclusions from this study will therefore be exclusively applied to the companies and not the general communities where these companies are located. Also, the study only assessed noise and particulate matter levels as the hazards of interest.

6.3 Conclusion

Quarry companies provide inadequate PPE. Although all participants reported using some form of PPE, a substantial proportion indicated minimal access to essential items such as helmets, ear plugs, gloves, and wellington boots.

The noise level at the quarry sites exceeded the safe limit for prolonged exposure, indicating that workers in both areas (crusher and security) were at risk of noise-induced hearing loss. However, the crusher areas presented the highest hazard than the security post due to its operations involving heavy machinery and material processing.

The PM levels at the crusher areas exceeded WHO limits but were within Ghana's daily standards. Workers at the crusher areas faced higher dust-induced risks compared to those at security posts due to elevated PM concentrations.

The study stresses the critical health risks associated with occupational exposures to noise and particulate matter at quarry sites. These risks include auditory damage, respiratory diseases, cardiovascular issues, and general systemic health problems.

6.4 Recommendations

Government of Ghana or Council for Scientific and Industrial Research (CSIR)

- ❖ Should invest in research on the impact of noise and PM on people living in the communities around the quarry companies.

Environmental Protection Agency (EPA):

- ❖ Must enforce strict compliance with occupational health and safety standards through regular inspections and stringent penalties for non-compliance.

The Quarry Companies

- ❖ Should ensure the availability and accessibility of all necessary PPE to their workers.
- ❖ Should establish an on-site medical facility, regular safety drills, and routine checks of safety equipment are essential for enhancing workplace safety.

Future Research

- ❖ Conducting longitudinal studies to monitor the long-term health effects of PM and noise exposure among quarry workers can provide deeper insights into the chronic health impacts of quarrying activities.
- ❖ Research should evaluate the effectiveness of various interventions, such as improved PPE, training programmes, and environmental controls, in reducing health risks and enhancing safety in the quarrying industry.

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		Tertiary level []	
A4	Marital Status	Single []	Ask respondent
		Married []	
		Divorced []	
		Widow/Widower []	
A5	Previous Work (How long)		Ask respondent
A6	Present Work		Ask respondent
A7	How many hours do you work per day		Ask respondent
A8	How long have you working at the Quarry?		Ask respondent

SECTION B: Occupational Health and Safety Practices (Questions & Answers from workers)

SN	Question	Response
B1	What type of duties do you perform at the quarry site?	Stone Blastering []
		Crushing Machine Operator []
		Manual Crushing []
		Collection of Stone from grinding machine []
		Loading Section []
B2	Years of experience on the job role	Less than 5 years []
		5-10 years []
		More than 10 years []

B3	What is your level of awareness on occupational health and safety issues?	Use of Respirators []
		Use of Nose/Mouth Mask []
		Use of ear plugs []
		Bathing before leaving work site for home []
		Change to clean clothes before going home []
		Other measures.....
B4	What type of noise are you exposed to?	Intermittent []
		Continuous []
B5	What is the source of noise exposure?	Specify.....
B6	What are the safety precautions you take here to protect against falls and slips?	Ladders are used to gain access to different heights []
		Safety belts are used when climbing heights without ladders []
		Walking or working areas are kept free of mud []
		Safety shoes are used []
		Other measures.....
B7	What are the measures in place to prevent risk of objects falling and harming workers?	Safety shoes with metal toes are always used []
		Workers are taught techniques for handling weights []
		Machines are used to handle weights if it is

		possible []
		All vehicles and tools for transport have a properly periodic maintenance []
		All lift wires are checked and replaced when a section is damaged []
		Working areas with risk of fall are properly marked []
		Safety helmet use is obligatory []
		Workers always avoid to stay below loads []
B8	What are the measures taken to reduce the risks from accidental blasts and vibrations?	All those elements and systems that may have risk of explosion are frequently inspected []
		In machinery for movement, drivers' seat has got suspension system []
		When using hand machinery that cause vibrations, workers alternate tasks []
		Other measures.....
B9	What are the measures in place against risk of dust inhalation?	Dust collectors are implemented in places with high dust levels []
		Workers have a hut to protect themselves from dust []
		Workers use masks []
		Protective glasses are used by workers []

		Workers wear protective clothes []
		Other measures.....
B10	What are the measures in place against risk of noise exposure?	Noise frames are used to reduce noise from the source []
		Noise levels are regularly monitored to take appropriate action []
		Workers have at their disposal hearing protection in function of their exposition to noise []
		Other measures.....
B11	What are the common hazards experienced at work site?	Physical Injury (Burns, Cuts, Falls, Slip, Eye irritations) []
		Noise Pollution []
		Dust Inhalation (Respiratory infections, Choking from dust) []
		Excessive Heat []
		Other measures.....
B12	What are the common signs and symptoms among quarry workers?	Body pains []
		Fever []
		Loss of appetite []
		Weakness []

		Occasioned cough []
		Persistent cough []
		Haemoptysis (coughing up of blood) []
		Mild breathlessness on exertion []
		Prolonged or severe breathlessness on exertion []
		Minor fatigue []
		Severe fatigue []
		Weight loss []
		Night sweat []
		Occasional chest pain []
		Persistent Chest Pain []
		Numbness of the extremities (hands and feet) []
		Injury at workplace []
		Impaired hearing []
		Eye itching []
		Skin rashes []
B13	Have you ever been informed by site owner/supervisor/colleague to use PPE?	Yes [] No []
B14	If Yes, why do you wear PPEs to protect yourself?	
B15	How often do you use these PPEs?	All the time []

	Face mask	Sometimes []	
		Not necessary []	
	Hand Gloves	All the time []	
		Sometimes []	
		Not necessary []	
	Wellington Boots	All the time []	
		Sometimes []	
		Not necessary []	
	Head cover/Helmet	All the time []	
		Sometimes []	
		Not necessary []	
	Eye Goggles	All the time []	
		Sometimes []	
		Not necessary []	
	Ear plugs	All the time []	
		Sometimes []	
		Not necessary []	
	B16	What is the main reason you don't use PPE?	Could not afford to buy []
			PPE not provided []
			Won't injure me because am careful when working []
			Feel uncomfortable when I wear PPE []
			PPEs not necessary []

SECTION C: Occupational Health and Safety Practices (Site Observational guide)

Focal Area/Issue	Observation
Falls from height	Check for use of ladders or safety belts
	Check if risk of falls are marked
Falls/slips	Check for presence of mud in walking or working areas
	Check adequacy of lighting in working and walking areas
Fallen/lose objects	Check for objects stored near quarry facades
	Observe workers use of safety helmets
	Check if workers stay below loads
	Check if a security distance of at least 5 meters between workers and radius of action of heavy machinery is followed
	Check if machines or tasks that can cause projection of fragments of material are covered with protection barriers (i.e.: transparent fronts between worker and machine)
Dust	Observe for the availability of dust collectors in place with high dust levels
	Check if workers use a hut to protect themselves from dust
	Check if workers use masks
	Check if workers use protective glasses
	Check if workers wear protective clothes
Noise	Check for use of noise frames to reduce noise from source
	Check workers use of hearing protection

Any other important observations made.
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APPENDIX II: RESULT FOR GRAPHS

Common Hazards Experienced		
Musculo-skeletal injuries	23	22.5
Hearing Loss	14	13.7
Falls	22	21.6
Respiratory Disease	11	10.8
Vehicle accidents	11	10.8
Blasting accidents	21	20.6

Figure 4.1

Reasons for Wearing PPE		
Against Falling Objects	8	7.8
Respiratory Hazards	12	11.8
Ear Protection from Noise	16	15.7
Eye Protection from Debris	13	12.7
Chemical Exposure	8	7.8
Sun and Heat Exposure	17	16.7
Crushing Hazards	12	11.8
Visibility	16	15.7

Figure 4.2

Type of Noise Exposure		
Intermittent	25	24.5
Continuous	77	75.5

Figure 4.3

Source of Noise Exposure		
Excavators and Loaders	10	9.8
Drilling Rigs	18	17.6
Use explosives for blasting rocks	12	11.8
Trucks and Haulage Vehicles	17	16.7
Conveyor Belts	20	19.6
Generators and Compressors	11	10.8
Alarms and Warning Systems	14	13.7

Figure 4.4

Common Signs and Symptoms Among Workers		
Body pains	14	13.7
Minor fatigue	10	9.8
Severe fatigue	6	5.9
Weight loss	5	4.9
Night sweat	6	5.9
Occasional chest pain	8	7.8
Numbness of the extremities	4	3.9

Injury at workplace	5	4.9
Impaired hearing	7	6.9
Eye itching	5	4.9
Skin rashes	4	3.9
Fever	4	3.9
Loss of appetite	2	2.0
Weakness	5	4.9
Occasional cough	5	4.9
Persistent cough	3	2.9
Hemoptysis (coughing up blood)	2	2.0
Mild breathlessness on exertion	4	3.9
Prolong breathlessness on exertion	3	2.9