SCHOOL OF PUBLIC HEALTH

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EMERGING DISEASES ASSOCIATED WITH MINING: A STUDY OF SMALL SCALE MINING COMMUNITIES IN GHANA

BY

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DECLARATION

I, Kwasi Safo Boakye, confirm that this work

'Emerging diseases associated with mining: a study of some mining communities in Ghana'.

Has not been previously submitted, either in whole or in part for a degree at this University or any other institution of higher learning. To the best of my knowledge the thesis is original and contains no materials previously published or written by any other persons except as acknowledged in the text and reference list.

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For Dr. Samuel Oko Sackey

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DEDICATION

I dedicate this thesis to my lovely wife; Major Belinda Naa Amorkor Amarteifio-Boakye, daughters Efua and Ewurasi. For all your love, care, commitment and support throughout schooling period; I am extremely honored and owe you the world. Thank you

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ABSTRACT

Background: Mining activities are a high prevalence of certain diseases compared to non-mining areas as a result of the environmental and social changes that create conditions that favor disease emergence over time. Over the years, most research on gold mining areas in Ghana have been from an economic perspective, with few looking into gold mining-related disease prevalence. This study is aimed to identify new diseases that emerge as a result of mining activities and exposures to hazardous chemicals.

Methods: This study was a quantitative cross-sectional design and a total of 504 participants from selected mining areas in the Amansie Central, Asante-Akyem district and East Akim Municipal district in Ghana were sampled. Data was collected through interviewing using semi-structured questionnaire. A logistic regression model was fitted to determine the association between selected exposure variables and some mining diseases.

Results: Mean age of the respondents was 33±9.1years and about 80% were males. The prevalence of mining related diseases were skin problems (39.2%), numbness in the palm and feet (34.2% and 33.8% respectively), respiratory problems (18.1%) and tremors (16.9%). About 68.8% of the miners worked with mercury and the majority burned amalgam or melted gold daily or at least once a week. Also 75.5% did not use hand gloves when working with mercury. Working with mercury was also associated with 3.72 times higher odds of numbness (AOR: 3.72; 95%CI: 2.21 -6.27) and skin diseases (AOR: 2.49; 95%CI: 1.51 -4.10). Handling mercury without gloves and handling mercury daily were also associated 1.99times higher odds of numbness and skin diseases. As compared to those who never burned amalgam, burning amalgam daily was associated with 2.01 times higher odds of numbness (AOR: 1.99; 95%CI: 1.14 -3.49) and skin diseases (AOR: 2.01; 95%CI: 1.12 -3.59)

Conclusion: This study found high prevalence of diseases related to mining activities including skin problems, numbness in the palm and feet, tremors and anxiety. It is urgent to adequately monitor and assess disease prevalence among small scale miners to adequately prepare the healthcare system for emerging health conditions.

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LIST OF ABBREVIATIONS

AIDS…………………..Acquired Immunodeficiency Syndrome

ANOVA………………Analysis of Variance

AOR……………………Adjusted Odds Ratio

BMI……………………Body Mass Index

COPD…………………Chronic Pulmonary Obstructive Disease

GFAA…………………Graphite Furnace Atomic Absorption Spectrometric Method

HIV……………………Human Immunodeficiency Virus

ICP………………...…..Inductively Coupled Plasma Method

PDMstyle………………Provider Decision Making Style

SES……………………Socio - Economic Status

SSM……………………Small Scale Mining

STD……………………Sexually Transmitted Disease

XRF ……………...…. X – Ray Fluorescence

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CHAPTER ONE

INTRODUCTION

1.1 Background

Mining, a human activity since pre-historic time, involves the extraction of valuable minerals or other geological materials or deposits from the earth. It is an important economic activity which has the potential of contributing to the development of areas endowed with the resource. In North America for instance, the mining industry employs approximately one million people (Mbendi Information Services, 2005) and in Ghana, the sector plays an essential role in the development of the economy. In 2000, minerals accounted for 38.96% of Ghana's total export earnings, followed by cocoa (22.51%) and timber (9.03%) (ISSER, 2001). The mining sector now contributes 41% to the country's foreign exchange and is the leading foreign exchange earner (Awudi, 2002).

Mining operations, however, usually create negative environmental impacts, both during the mining activity and after the mine has closed. Pollution caused by quarrying and blasting in mines increases the dust particles in the air and the surrounding environment and promotes the spread of toxic chemicals such as cyanide and sulfur dioxide, which are all very harmful to the body (Martin, Dowling, Pearce, Sillitoe, and Florentine, 2014). In addition, arsenic, which is used in processing the crushed rock, flows into streams and rivers, the major source of drinking water for local residents. This emanates from the methods of operation by the mining companies, its effects on the natural environment as well as the people in the surrounding communities. In Ghana, activities of illegal miners have caused extensive damage to forest vegetation and water bodies that serve as sources of drinking water to millions of people (Boadi, Nsor, Antobre, and Acquah, 2016; Eshun, 2017).

In Ghana, previous research in gold mining towns show that upper respiratory tract infections and skin rashes are exacerbated due to mining activities (Akabzaa and Darimani, 2001; Awudi, 2002). Conjunctivitis, respiratory tract diseases, vector borne diseases such as malaria, schistosomiasis and STDs such as HIV/AIDS may also be intensified in mining areas (Vora, 2008; Zhang et al., 2010). The environmental and social changes associated with mining also create conditions that favor disease emergence over time. For example, in 1995, an Ebola outbreak occurred in Mékouka and other gold-mining camps deep in the rain forest of Gabon with a mortality rate of 60 percent (Awudi, 2002). An outbreak of *Lymphocutaneous Sporotrichosis*, a tropical fungal disease, also occurred among mine workers employed at a gold mine close to the town of Barberton in the sub-tropical north-eastern Lowveld area of South Africa (Govender et al., 2015). The largest outbreak of *Sporotrichosis* also occurred between 1938 and 1947 in the gold mines of Witwatersrand in South Africa (Govender et al., 2015).

1.2 Problem statement

The environmental and social changes associated with mining that create conditions that favor disease emergence over time. Mining areas there therefore characterized by a high prevalence of certain diseases compared to non-mining areas. High levels of arsenic have been found in ground water in mining areas in Ghana, the long-term exposure of which, may cause a wide range of health effects, including skin lesions, circulatory disorders, diabetes and cancers of the bladder, lung, kidney, and liver (Ahoulé, Lalanne, Mendret, Brosillon, and Maïga, 2015; Asante and Ntow, 2009). However, over the years, most research on gold mining areas in Ghana have been from an economic perspective, with few looking into gold mining-related disease prevalence. In Ghana studies are scares. examining the emergence of mining-related diseases in mining areas of Ghana. Monitoring the emergence of diseases in mining areas will ensure timely prevention and management of diseases to curtail possible disease outbreaks and epidemics in mining areas in Ghana**.**

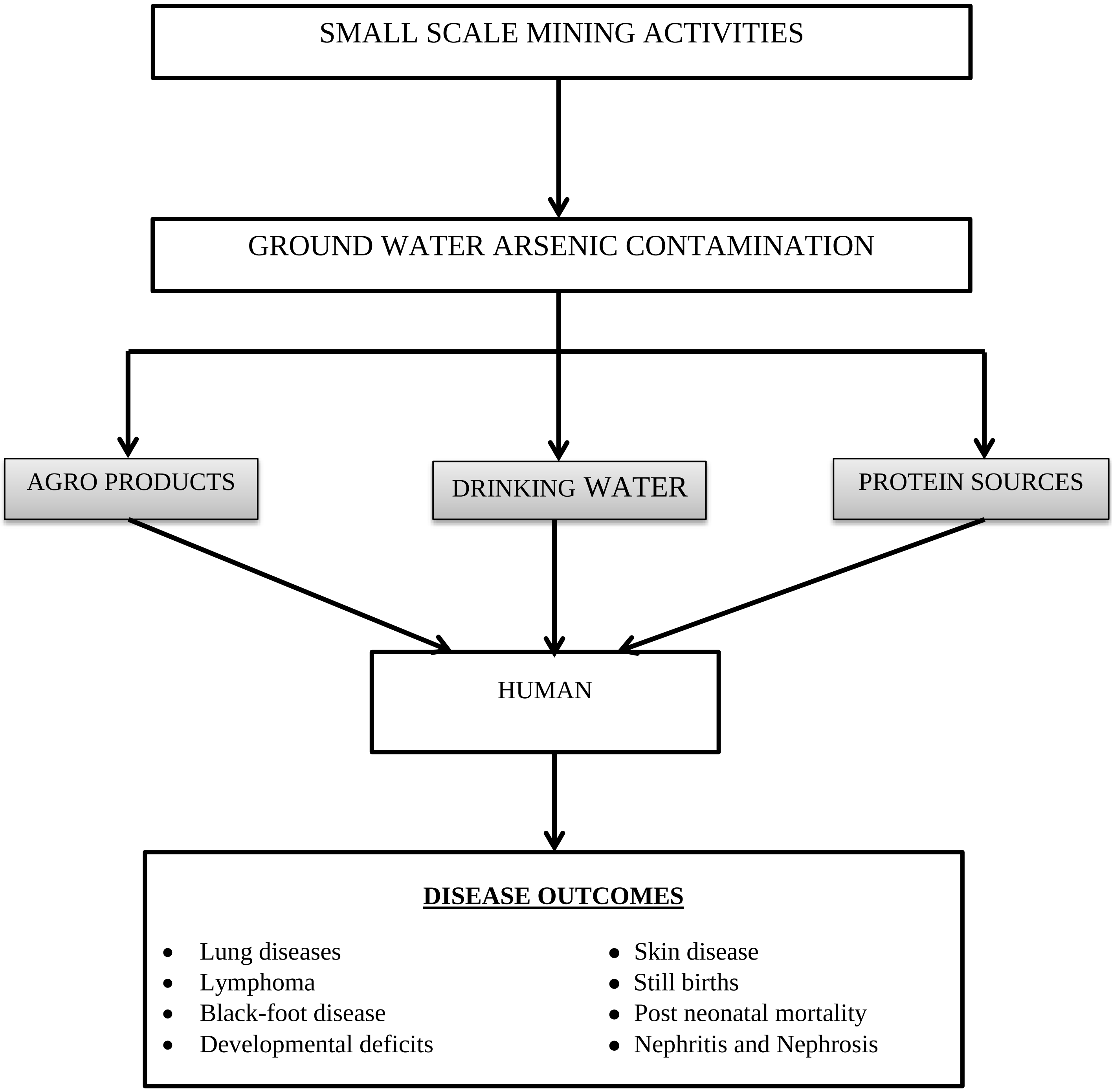
1.3 Significance of the study

This study is important for two reasons. First, it contribute to knowledge in the field of mining and health and provides insight into the emerging diseases that are attributed to mining activities and related exposures in Ghana. Second, it provides a basis for timely prevention and management of diseases by the health sector to curtail possible disease outbreaks and epidemics in mining areas in Ghana.

1.4 Conceptual framework

Figure 1 is the conceptual model showing how the arsenic contamination leads to disease outcome among small scale miners in Ghana. As illustrated, arsenic contaminates water bodies when it flows into streams and rivers through the methods of operation by the mining companies. Ground water, contaminated with arsenic directly affects humans' sources of drinking water, sources of proteins and also affects agro products. Through consumption of contaminated agro foods and protein from fishes and livestock, and or direct drinking of the contaminated water, arsenic gets transferred to humans. This leads to the development of diseases such as lymphoma, black-food disease, skin and lung diseases among humans.

Figure 1.1: Conceptual framework



1.5 Objectives of the study

1.5.1 General objective

This study aimed to identify new diseases that emerge as a result of mining activities and to assess the factors that are associated with these mining related diseases.

1.5.2 Specific objectives:

1. To determine the prevalence of diseases in mining areas in Ghana
2. To assess emerging diseases that are attributable to mining activities in Ghana
3. To assess factors that are associated with mining related diseases in Ghana

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview of artisanal and small-scale mining in Ghana

Artisanal or small-scale mining is a makeshift process to extract valuable minerals from primary and secondary ore bodies. This is characterized instituted long-term mine planning/control (Hinton et al, 2003a). It encompasses either formal or informal process and from individual gold panners to large-scale operations that employ thousands of people. It is worthy to indicate that, artisanal and small-scale mining operations form the backbone of several livelihoods of developing rural communities especially in Africa. It is estimated that there are 11 to 13 million artisanal miners worldwide, with 80 to 100 million people directly or indirectly dependent on artisanal miners for their livelihood (Jennings, 1999). Hazards associated with artisanal small scale mining include: poor ground conditions leading to underground failure, methane or coal dust explosions from coal mines, flooding, machinery accidents, poor lighting and ventilation, explosives accidents, and electrocution (Priester et al, 1993). In artisanal and small scale mining, mercury, cyanide and other hazardous chemicals are used as reagents for recovering and purifying gold and other precious metals. Fine dust from mineral processing, leading to silicosis and noise pollution are endemic problems (Hinton et al, 2003a).

Historically, the Ghanaian small-scale mining industry is well over 2,000 years old (Hilson, 2001). Gold extraction and winning activities begun as far back as the sixth century, and there is a wealth of evidence indicating that precious metals recovered from regional artisan activities were attracting Arab traders to certain areas of the country as early as the 7th and 8th centuries AD (Hilson, 2001). History indicates that, it was the rich gold deposits of the western Sahara that were largely responsible for the wealth and strength of large ancient

Ghanaian empires and cultures, and by the 15th and 16th centuries, at the peak of European colonial exploration, Ghana was fittingly labelled the 'Gold Coast'.

Small-scale mining in Ghana, was for decades treated as an informal industrial sector. Up until the 1980s, small-scale mining activities in Ghana remained largely unregulated and received little, if any, support from governmental bodies. This, however, changed with the implementation of the national Economic Recovery Plan (ERP), which, following years of careful planning, was finally launched in the mid-1980s. The Ghanaian minerals sector was heavily targeted, which, between 1960 and 1980, had experienced mass declines in mineral output: gold production had declined from 900,000oz in 1960 to 232,000oz in 1982; manganese output had dropped from 600,000t in 1960 to 160,000t in 1982; bauxite production declined from 407,000 in 1974 to 64,700t in 1982; and diamond output had declined from 2,340,000 carats in 1975 to 683,524 carats in 1982 (Hilson, 2001).

The growing importance of artisanal and small mining in Ghana, cannot be overlooked. The contribution of small scale mining to wealth creation, employment and the economy makes it one of the nation's most important livelihood activities. It is known that small scale mining in Ghana employs an estimated one million people and supporting approximately 4.5 million more people (McQuilken and Hilson, 2016). Small scale mining accounted for 35% of Ghana's total gold production in 2014, contributing almost 1.5 million ounces of gold. Yet the majority of miners in Ghana operate informally, without the security of a licence (McQuilken and Hilson, 2016).

In Ghana, small scale mining employs a wide range of individuals. These individuals undertake diverse roles, from general labouring to skilled machining, supervising and bookkeeping. The majority are poverty-driven, from families and individuals trying to earn enough to survive, young students funding their school and university education, and farmers supplementing their income, to larger labour groups comprising men, women and children. Women constitute up to 50% of the labour force and are engaged largely as haulers and washers, and service providers. In addition to these poverty-driven livelihoods, there is also a burgeoning number of well-educated and well-connected ‘greedy industry players” who, due to their unique position and access to significant capital investment, are able to navigate the complex sociopolitical and bureaucratic landscape needed to obtain a license (Hilson, 2001; McQuilken and Hilson, 2016).

By the end of the 1980s, government had fully regularized the small-scale mining sector through a series of policies and regulations however majority of miners in Ghana today operate informally usually without license particularly due to barriers associated with obtaining land and a license which are often bureaucratic and often times political (McQuilken and Hilson, 2016). This has therefore given rise to a host of environmental and social problems in Ghana, such as the pollution and destruction of water bodies, degradation of arable farmland, as well as the negative health impacts of working in hazardous conditions; this has been the focus in the Ghanaian media, which tends to depict the entire small scale mining sector in a negative and damaging light.

Formalizing Ghana’s informal mining sector is therefore a significant, timely and pressing developmental opportunity that should be realized. The most significant challenges facing Ghanaian small-scale miners and communities are access to equipment and formal finance, and, most pressingly, difficulties in obtaining a license. These all stem largely from a shortage of untitled land for small scale mining activities and accompanying geological records, without which it is difficult to obtain formal finance. Finance is needed to cover the cost of acquiring land and to meet the requirements of obtaining a license and an environmental permit. These issues both inhibit and discourage the majority of prospective miners who are driven by poverty and lack sufficient social capital and financial and technical resources from formalizing their activities (McQuilken and Hilson, 2016).

2.2 Diseases associated with mining

Mining is an important economic activity in both developed and developing countries. Despite the enormous economic benefits associated with gold mining, its detrimental effects on the environment and health of miners cannot be overlooked. Both surface and underground mining activities, are associated with numerous health externalities and exposure to dust and chemicals from mining causes acute and chronic respiratory diseases (Ayaaba, Li, Yuan, and Ni, 2017). The situation is more detrimental in limited resource settings, where mining regulations are less enforced and the safety of miners is of less concern.

In 2017, a study was conducted to investigate respiratory disorders among gold miners in the Tarkwa an Obuasi mines in Ghana using a cross-sectional exploratory design among 1001 male workers (505 and 496 underground and surface miners) (Ayaaba et al., 2017). The study reported high prevalence of respiratory disorders. The prevalence of asthma, pneumonia, bronchitis and emphysema were respectively 47.55%, 14.29%, 9.69% and 5.10%. The prevalence of respiratory symptoms ranged from 35.4% of coughing to 25.4% of chest pain (Ayaaba et al., 2017). A literature review of the prevalence of Chronic Obstructive Pulmonary Disease (COPD) including emphysema in Africa, reported a high variation in prevalence, ranging from 5.3% to 47% (Mehrotra, Oluwole, and Gordon, 2009).

2.3 Environmental impacts of gold mining

Mineral processing is also associated with the presence of hazardous chemicals which are detrimental to human health. For example, arsenic in dust, is a serious threat to human populations throughout the world. Major sources of contamination include smelting operations, coal combustion, hard rock mining, as well as their associated waste products, including fly ash, mine wastes and tailings (Martin et al., 2014). The number of uncontained arsenic-rich mine waste sites throughout the world is of growing concern, as is the number of people at risk of exposure. Inhalation exposures to arsenic-bearing dusts and aerosol, in both occupational and environmental settings, have been definitively linked to increased systemic uptake, as well as carcinogenic and non-carcinogenic health outcomes (Martin et al., 2014).

Arsenic and inorganic arsenic compounds are classified as Group 1 carcinogens and are associated with cancers of the lung, bladder, kidney, skin, liver and prostate (IARC, 2012). Exposures to arsenic compounds are however increased with exposure to emission source. Emissions of arsenic-bearing particulate matter are of particular concern for human populations living in proximity to an emission source. Arsenic inhalation is considered a minor exposure pathway for inorganic arsenic compounds, whiles ingestion is considered the primary exposure pathway (IARC, 2012). However, populations living in the vicinity of an arsenic emission source have an increased risk of additional exposure through inhalation of arsenic-contaminated particulates (Yang et al., 2012).

A study was conducted to evaluate the effects of an abandoned arsenic mine on drinking water resources quality and possible health effects on the residents of mining area in the North West of Iran in 2011 (Hajalilou et al., 2011). Water samples were collected and analyzed for chemical parameters according to standard methods. For determination of arsenic in water samples, Graphite Furnace Atomic Absorption Spectrometric Method (GFAAS) and for wheat samples X – Ray Fluorescence (XRF) and Inductively Coupled Plasma Method (ICP) were used. Information about possible health effects due to exposure to arsenic was collected through interviews in studied villages and health center. Arsenic concentration ranged from zero in some villages up to 2000 µg/L in mine opening. The concentration of arsenic in the water increased with increasing proximity to the mine. The highest concentrations of arsenic were inside and near the mine that with increasing distance from the mine, the concentrations were decreased (Hajalilou et al., 2011).

Previous research in Ghana found high levels of mercy in the mining environment, which was reported to be a result of its use in gold recovery process where the inorganic form of the metal is either washed into rivers or readily vaporized into the atmosphere. The use of mercury by illegal miners has been linked to increased cases of kidney diseases in Ghana (Kusi-Ampofo and Boachie-Yiadom, 2012). Mercury affects the renal system, nervous system, gastrointestinal tract and respiratory system (Obiri et al., 2016). One report estimated that 5 tons of mercury is released from small-scale mining operations in Ghana each year (Ragnar and Björn, 2005).

A study of five mining communities in the Obuasi Municipality of Ghana also found prevalence of mining related diseases among the residents as a result of exposure arsenic in water bodies (JH Yeboah, 2008). The study was conducted to assess the health impact of AngloGold Ashanti's mining operations on the residents in these areas. Skin diseases were reported principally by workers and residents from two of the communities studied; Anyimadokrom (26.6%) and Sanso (24.3%). The skin diseases were due to chemical contamination of water bodies which some residents are dependent on for water, food and other domestic purposes. The high occurrence of skin diseases at Anyimadokrom is attributed to its proximity to AngloGold Ashanti's Pompola treatment plant where chemicals such as arsenic (sulfur dioxide) are used. In this study, other communities which were far from the mining site had low prevalence of mining related diseases (JH Yeboah, 2008).

The endemic nature of Buruli ulcer in Ghanaian communities adjacent to mining activities also suggests that proximity to artisanal and small-scale gold mining is a risk factor for this disease, as is the case of the higher prevalence of Buruli ulcer in the Amansie West District in the Ashanti Region of Ghana (Duker, Stein, and Hale, 2006). The spread of Buruli ulcer might not be linked with direct participation in mining in this area, but it is reported to be associated with changes in land use that accompany small-scale mining activities such as stream bed (Merritt, Benbow, and Small, 2005).

2.4 Mercury use in artisanal and small-scale mining

The practice of using mercury to extract gold is an ancient practice that dates back to the twentieth century. Even though it was outmoded over a period of time in the late twentieth century, the gold rushes in Latin America began during the 1970s and 1980s led to its resurgence (Veiga, 1997). Due to its simple effectiveness and practicality, mercury is virtually ubiquitous with small-scale gold processing. The major process of artisanal small scale gold mining that involve the use of mercury is amalgamation (Ntalikwa, 2015). Amalgamation is an ancient process which involves the alloying of the gold particles with metallic mercury to form amalgam and then the separation of the gold from the mercury by heating in retorts until the mercury is distilled off. This process is strongly out of favor with the major mining companies, due to the extremely toxic nature of mercury and the processes inferior performance when compared to the available alternatives. Following this, gravity concentration is used to create movement between the gold and host rock particles in a manner to separate the heavy pieces from the lighter pieces of material. The material is then panned. Panning is a type of gravity concentration used by artisanal gold miners for the recovery of gold from river beds mostly with their bare hand. It concentrates the heavy gold particles at the bottom of the pan while the light gangue is washed off on top (Ragnar and Björn, 2005).

2.5 Hazard of mercury use in artisanal and small-scale mining

Even though the use of mercury in small scale mining is a simple and inexpensive, there are several hazards associate with the use of mercury in small scale mining. In a typical artisanal gold mining, accidents are often underreported, due to the illegal or semi-legal status of most their operations and the use of mercury is one of these. While artisanal small scale mining operation may be relatively small, the practice is widespread especially in developing countries including Ghana. The operations handle extraordinary amounts of mercury directly by the miners and released into the environment, leading a huge burden on human (Ragnar and Björn, 2005). Mercury vapor inhaled by miners results in impaired cognitive function, neurological damage, kidney damage and several other health problems (Esdaile and Chalker, 2018). In many cases, where mercury amalgams are processed near the home or in gold shops in villages or cities, so the mercury vapor generated in the process affects non-miners living in these areas. Exposure to mercury pollution is especially dangerous as it increases the likelihood of physical deformities, neurological damage and lower intelligence (Esdaile and Chalker, 2018).

The high levels of mercury that accumulate in fish and other food supplies in artisanal and small scale mining communities further increases the risks associated with mercury exposure. Mercury poisoning is a tremendous burden to human health, especially in these mining communities (Esdaile and Chalker, 2018). Mercury gas, such as that encountered in amalgam processing, is readily absorbed in the lungs and then further transported to other organs. Elemental mercury is able to cross membranes including the blood–brain barrier and the blood-placenta barrier, posing a threat to neurological function and fetal development, respectively (Mensah, 2012). Acute mercury exposure can lead to tremors, memory loss, respiratory distress and even death (Erdiaw-kwasie, Mabunyewah, and Mabunyewah, 2012). Chronic exposure to mercury gas may lead to renal failure, tremors, movement disorders, and various psychosis and memory impairment (Han, Chen, Harvey, Stemn, and Cliff, 2018).

Inorganic mercury, formed through oxidation of mercury metal lost during small scale mining contaminate water and also lead to kidney damage if consumed by rural folks in mining areas (Esdaile and Chalker, 2018). Conversion of mercury pollution from small scale mining into methyl mercury also a lead to highly toxic form of mercury accumulates in food supplies, such as fish, crustaceans and mollusks. Consumption of methyl mercury is particularly harmful to the central nervous system, causing nerve and brain damage. Kidneys are also affected and methylmercury presents an extreme risk to fetal development (Erdiaw-kwasie et al., 2012; Joseph, 2008).

2.6 Clinical signs and symptoms of mercury

In many developing countries, mercury poising is underreported. What is of great concern however is that, mercury poisoning is frequently misdiagnosed because of the gradual onset and its associated nonspecific signs and symptoms (Mensah, 2012). The clinical presentation of an individual exposed to mercury depends upon the dose, the length of and form of exposure. Acute toxicity is more commonly associated with the inhalation of elemental or ingestion of inorganic mercury. Chronic toxicity is more common from exposure to organic mercury. Irrespective of the chemical form of mercury present, the kidneys and the central nervous system are the two primary target organs of toxicity. All mercury compounds concentrate in the kidney to some extent. Acute exposure caused by inhaled elemental mercury can lead to pulmonary symptoms. Initial signs and symptoms, such as fever, chills, metallic taste and pleuritic chest pain may occur. Other possible symptoms could include stomatitis, lethargy, confusion and vomiting. Chronic exposure usually results from prolonged occupational exposure to elemental mercury that is converted into the inorganic form. Chronic and high dose acute mercury exposure produces a variety of renal, neurological, psychological and cutaneous symptoms. The exposed individual may experience rather vague and non-specific symptoms, including weight loss, fatigue, anorexia and muscular weakness that could be indicative of a number of diseases.

CHAPTER THREE

METHODOLOGY

3.1 Study design

This study was a quantitative cross-sectional design and employ quantitative methods. Data for this study was collected using structured questionnaires. Data on experiences of mining-related diseases as well as the socio-demographic characteristics was collected on a randomly selected population.

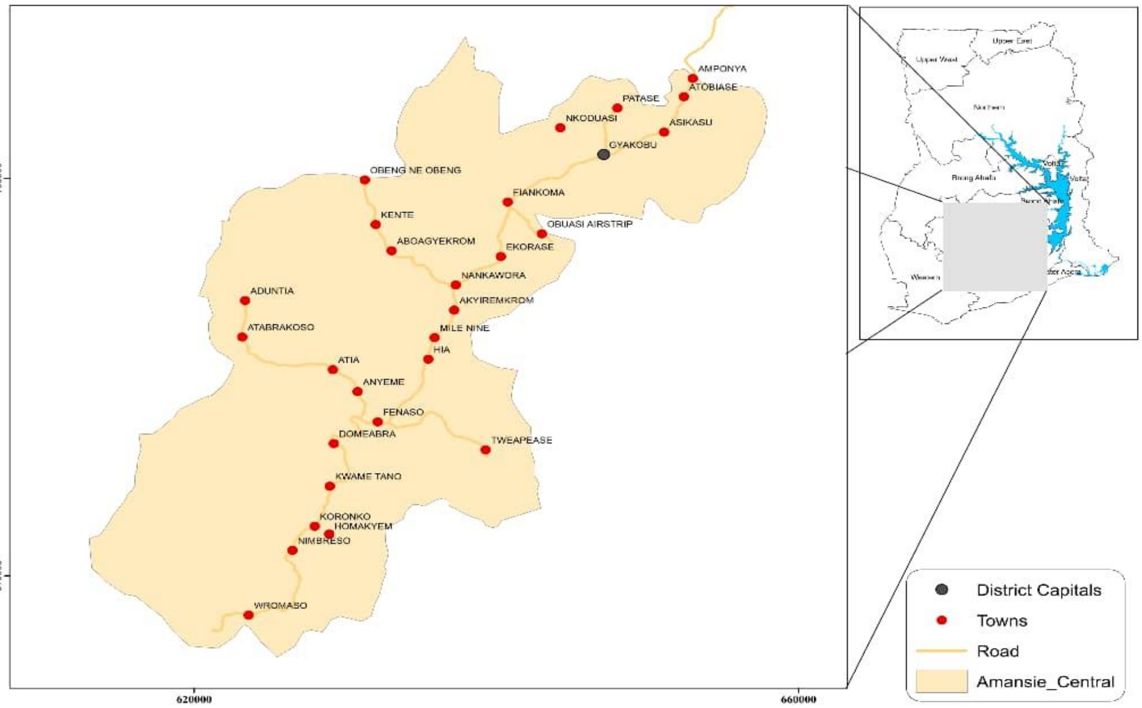
3.2 Study area

The selected mining areas were Jacobu in the Amansie Central district and Konongo in the Asante-Akyem district both in the Ashanti region of Ghana and Kibi in the East Akim Municipal district in the Eastern region of Ghana.

Amansie Central

The population of Amansie Central District is 90,741 representing 1.9 percent of the region's total populace (2010 Population and Housing Census). Males institute 49.9 percent and females 50.1 percent. Almost 89 percent of the population is rural. The population of the district is youthful (42.9%) depicting a broad base population pyramid which points off with a small number of elderly persons (5.7%). The total age dependency ratio for the District is 94.9, the age dependency ratio for males is higher (97.4) than that of females (92.4). Of the populace 11 years and above, 73.9 percent are literate and 26.1 percent are non-literate. The proportion of literate males is higher (92.4 %) than that of females (81.7%). About 70 percent of the population (69.9%) can speak and write both English and Ghanaian languages. About 76.6 percent of the populace aged 15 years and older are economically active. Of the economically active population, 95.9 percent are employed while 4.1 percent are unemployed. For those who are economically not active, a large percentage of them are students (50.5%), 24.0% perform household duties and 6.7 percent are disabled or too sick to work. Seven out of ten unemployed are seeking work for the first time. The main work in this district is skilled agricultural, forestry and fishery workers.

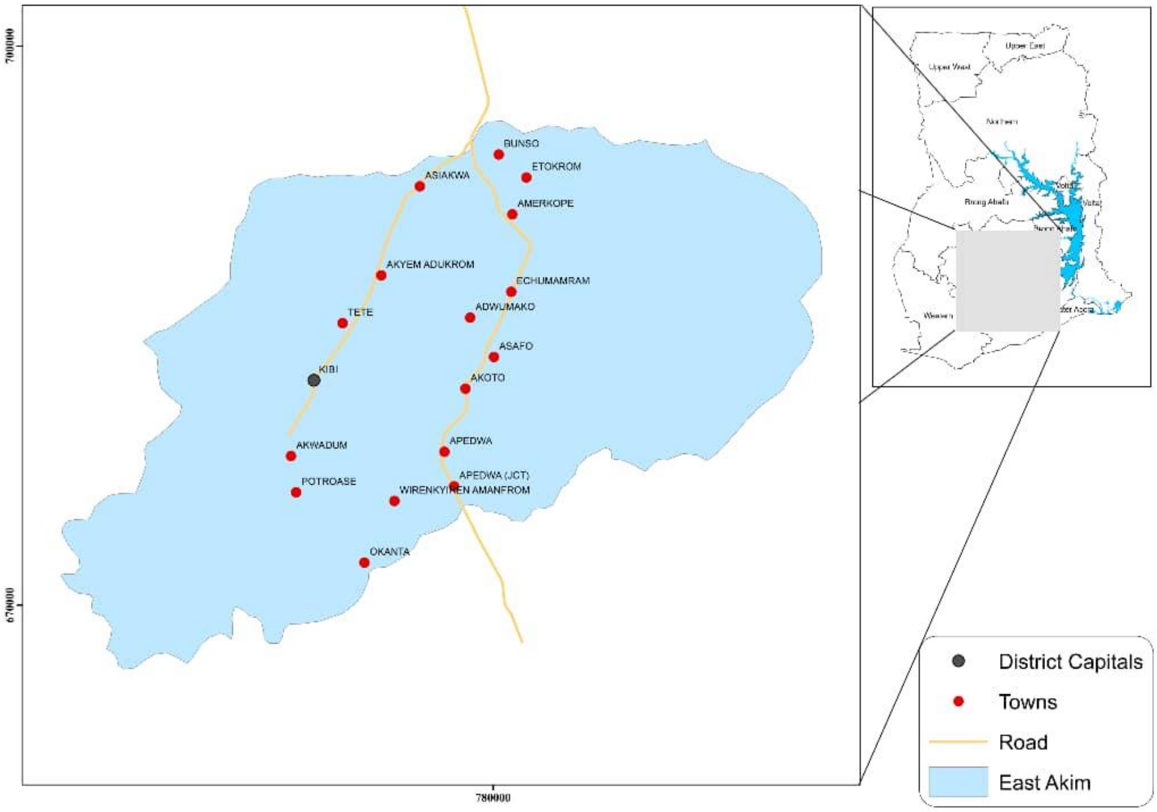
Figure 3.1 : Amansie Central district



East Akim

The people of East Akim District, giving by the 2010 Population and Housing Census, is 167,896 representing 6.3% of the region's total populace. Males institute 49.7 % and females 51.3%. Almost 40% of the population is rural. The district has a sex ratio of 94.9%. The population of the district is youthful 35.9% depicting a broad base population pyramid which points off with a small number of elderly persons 6.7%. The total age dependency ratio for the District is 74.3 of the populace 11 years and above, 71.0 percent are literate and 29.0 percent are non-literate. The proportion of literate males is higher 50.4 % as compared to females 49.6%. About 71.1% could speak and write both English and Ghanaian languages. 67.9 Economically of the populace aged 15 years and above are economically active, The main work in this district is skilled agricultural, forestry and fishery workers.

Figure 3.2: East Akim district



Asante Akim central

Asante Akim Central is municipal in Ashanti Region with a population of 71,508, 33,942 males 37,566 females. (2010 Population and Housing Census). The Municipality is surrounded by Sekyere East District on the north, Kwahu South District on the east, Asante Akim South Municipal on the south and Juaben Municipal on the west. 78.0% are literate and 22.0% are non-literate. The proportion of literate males is higher 51.4 % as compared to females 48.6%. About 70.1% could speak and write both English and Ghanaian languages. Its land is fertile for Farming and also rich in minerals like Gold. Major activity is Farming.

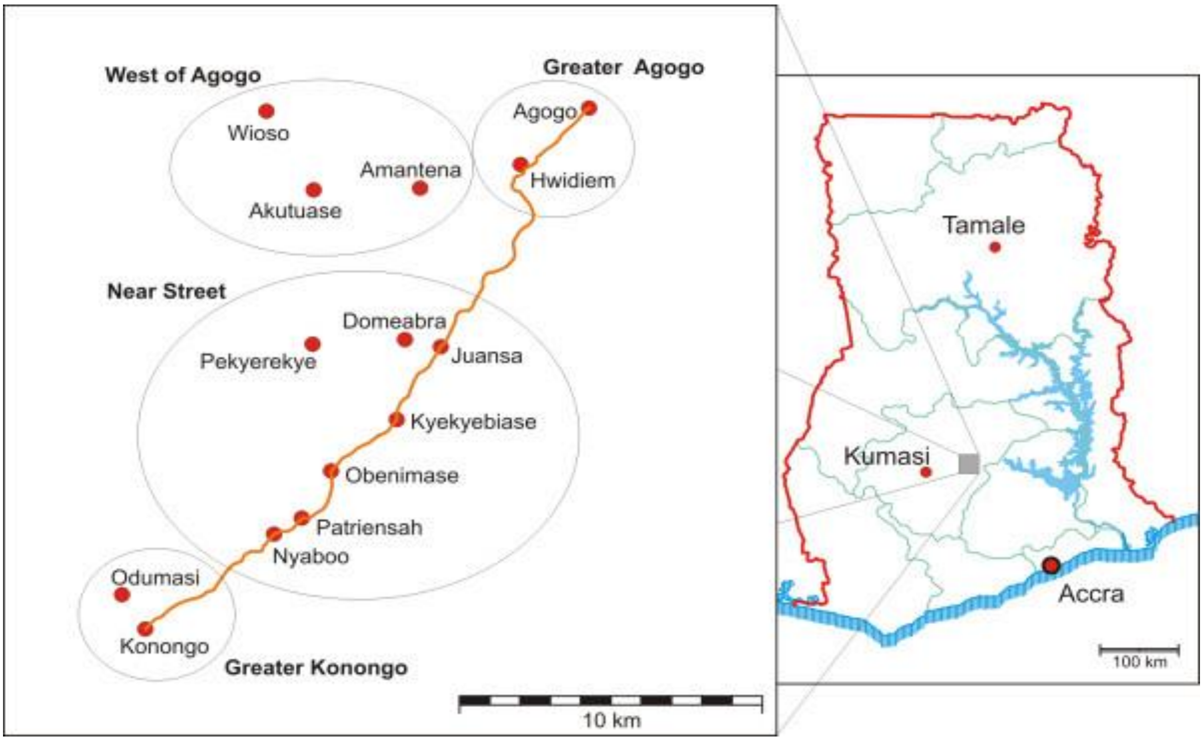


Figure 3.3: Asante Akim district

3.3 Study population and sampling

This study was conducted among Ghanaians (>18years) residing in mining areas in Ghana.

The inclusion criteria was:

- Having lived in the community for not less than one year and voluntarily consenting to participate in the study.

The exclusion criteria was:

- Participants who had resided in the community for less than one year

Sample size estimation

A total of 504 participants were involved in the study. This was estimated with recourse to the formula by Kirkwood and Sterne (2003);

$$n = \frac{Z^2 pq}{d^2}$$

Where n = the desired sample size

z = the standard normal deviation 1.96

p = the prevalence of mining related diseases in Ghana, assumed to be 50% (0.50) based on the scarcity of data on the prevalence of mining related diseasese

q = 1.0-p

d = degree of accuracy desired at 0 .05

$$n = \frac{(1.96)^2 (0.50) (0.50)}{(0.05)^2}$$

n = 384.16

20% of non-respondent effect would be used to comprehend the sample size, making a total of approximately 461.

The required respondents from each district was shared equally across the three towns due to the fact that the number of miners are not known. The distribution of respondents according to the study sites was Jacobu 154, Konongo 154 and Kibi 154. However, the data collected slightly exceeded the minimum required sample size and all the 504 respondents were included. The final sample size for the study sites 168 respondents per site.

Sampling of participants

A clustered random sampling technique was used to select respondents for this study. In the selected communities, the required respondents were selected first by clustering the communities, using the four cardinal points. Households were then selected using a sampling interval that was determined by the number of households divided by the sample size. In the selected households, respondents were sampled using the lottery method where pieces of papers with inscriptions “Yes” and “No” was written for picking. Respondents who picked “Yes” and consented to participate in the study were enrolled.

3.4 Study variables

The outcome variable was prevalence of mining related diseases. The explanatory variable will be the socio-economic characteristics including occupation, income, education, duration of exposure to mining environment and proximity to the mining site.

Table 3.1 Study variables

Variables	Description	Scale
Dependent variables		
Mining related diseases	Self-report assessment of skin diseases, respiratory problems, hepatic diseases, major infections like tuberculosis, anxiety, numbness in palm and feet, tremors. Presence of disease=1; Absence of disease = 0.	Binary
Exposure /independent variables		
Socio-demographic/background characteristics		
Age	Age of respondents in years	Continuous
Sex	Sex of respondents; male=1, female=2	Binary
Education	Educational level of respondents; no formal=1, basic=2, Senior High School=3, post-secondary=4, tertiary=5	Ordinal
Marital Status	Married=1, cohabiting=2, single=3, divorce or widowed=4	Nominal
Employment status	Respondents' employment status; employed=1, unemployed=2	Binary
Duration of stay in community	Length of stay of respondents in their respective communities	Continuous
Monthly income	Total monthly income from all economic activities	Continous
Work-related characteristics		
Job description	Description of job; e.g. Agriculture, small scale mining, clergy etc	Nominal

Description of small scale mining activities	Pit work illegal mining=1, grinding=2, washing=3 and melting=4	Nominal
Duration of work	How long one has worked in small scale mining	Continuous
Mercury exposure	Working with mercury, number of times work with mercury, use of hand protection, frequency of melting amalgam, frequency of melting gold	
Food and consumption characteristics		
Fish consumption	Frequency of consuming fish; never=1, occasionally=2, often=3	Nominal
Consumption of foods produced locally	Consuming chicken, ducks, eggs, meat, fruit and vegetables, milk; never=1, occasionally=2, often=3	Nomial
Sources of water	Household sources of water for cooking, drinking and other household chores: borehole=1, rive/stream=2, pipe-borne water=3, sachet water=4	Nominal
Lifestyle and health status		
Perceived health status	Whether one perceive him/herself to be healthy (1) or not (2)	Binary
Smoking status	Whether one smoke cigarette (1) or not (2); quantity of cigarette smoked	Binary; continuous
Drinking status	Whether one drink alcohol (1) or not (2); type and quantity of alcohol consumed	Binary; continuous
Sleeping problems	Whether one has problems with sleeping (yes=1; no=2) and the perceived causes of sleeplessness	Binary

Description of mining activities

Pit work: This procedure of mining is different from extractive techniques that require excavating into the earth, such as long wall mining. Open-pit mines are used when deposits of commercially useful ore or rocks are found near the surface. It is applied to ore or rocks found at the surface because the overburden is relatively thin or the material of interest is structurally unsuitable for tunneling. In divergence, minerals that have been found underground but are difficult to salvage due to hard rock, can be reached using a form of underground mining. But for illegal miners they dig tunnels of about 40ft down the earth and the dig more than 200ft across it, in such of rocks that they believe to be of quality for gold processing. Most often because of lack of experience these miners often get trapped in their dug pits, resulting in death.

Figure 3.4: A dug pit at and artisanal small scale mining

Grinding: The rocks that the pit workers bring, are broken into smaller pieces and grinded in a grinding machine, in a semi closed area. The grinders do this without any protected device, exposing them to all sort of inhalations causing serous chest infections.

Figure 3.5: Artisanal small scale miners at work

Washing: Small-scale gold mining operations mostly use mercury to separate the gold from other materials. Mercury is mixed with the materials containing gold. An amalgam is then formed, since gold will melt in the mercury while other impurities will not. The small scale miner for lack of equipment's or machinery will used his hand for trapping the gold with the mercury in the palm. This really exposes them of the toxicity of the mercury. They normally wash standing in stagnant water, and the still exposing their feet to the mercury that may fall into the water, because the water is never changed, but topped as and when it reduces.

Figure 3.6a: Artisanal small scale miners at work

Figure 3.6b: Artisanal small scale miners at working without hand gloves

Melting: The refining of the extracted gold is washed under a crude method, where concentrated tetraoxosulphate (IV) acid is used to burn and get the shiny gold we see.

3.5 Data analysis

Data was analyzed using STATA 15. The results are presented in tables and figures. Data was described using proportions for categorical variables and mean and median values for continuous variables. Univariable associations was tested using t-test (continuous), chi-square (categorical) and one way analysis of variance (ANOVA) where applicable. A logistic regression model was fitted to determine the association between exposure variables (type of SSM, work duration with SSM, working with mercury, how mercury is handled, frequency of handling mercury, and burning amalgam) and mining related diseases (skin dieseases and numbness). All statistical tests were conducted at a significance level of $p<0.05$.

3.6 Ethical considerations

Ethical clearance for this study was obtained from Ghana Health Service Ethical Review Committee and permission was also be sought from the Directorate of Health Service from the various districts. Informed consent was sought from all the respondents before interviewing them. The purpose and the objectives of the study, and any potential risk or benefits inherent in the study was explained to the respondents. The respondents were given an opportunity to ask questions about the study. Privacy and confidentiality will was ensured by dealing with the respondents on individual basis and conducting interviews in confined locations. Participants were offered the opportunity to decline to take part in the study or to withdraw at any stage of the research.

CHAPTER FOUR

RESULTS

This chapter presents the results of the study. The results are presented in tables and figures preceded by a narration.

4.1 Background characteristics of respondents

Table 4.1 presents results of the background characteristics of respondents involved in this study. The mean age of the respondents was 33±9.1years and about 80% were males. About 26% of the respondents had Junior Secondary School education whereas 35.3% had Senior Secondary School education. About 12% had not formal education. The majority of the respondents earned up to GHS 1000.00 monthly with 42.7% earning less than GHS 500.00 as monthly income. Almost 45% were married and the median (range) number of children born and alive 2 (0-10) and 1 (0-8) respectively. The age children died was given as <1year (n=1), 2years (n=2), 3years (n=1) and 4years (n=2). The cause of death was sickness (3) and spiritual (1) and at birth (3). About 8 respondents had ever given birth to children with deformities. The birth defects stated were blindness (n=2), eye problem (n=1), hearing impairment (n=1) and sickle cell (n=1).

Table 4.1 Background characteristics of respondents

Variables	Frequency	Percentage
Age in years, mean±SD	33±9.1	
Sex (n=476)		
– Male	383	80.5
– Female	93	19.5
Education status (n=487)		
– No formal education	59	12.1
– Primary education	126	25.9
– Junior Secondary	172	35.3
– Senior Secondary	116	23.8

– Tertiary education	14	2.9
Monthly income, GHS (n=466)		
– <500	199	42.7
– 500-1000	182	39.1
– 1001-1500	52	11.2
– >1500	33	7.1
Marital status (n=480)		
– Single	203	42.3
– Married	215	44.8
– Seperated	42	8.8
– Divorced /Widowed	20	4.1
Number of children (n=375), median (range)	2 (0-10)	
Number of children born alive (n=369), median (range)	2 (0-10)	
Number of children died (n=25), median (range)	1 (0-8)	
Any children with birth defects (n=432)		
– Yes	8	1.9
– No	424	98.1

Source: Field data, 2019

4.2 Habitat and work exposure characteristics of respondents

Table 2 also shows the results of habitat and other characteristics relating to work exposure among the respondents. The majority (59.7%) had resided in the area for more than 5 years and were employed (65.1%). Most of the respondents (66.9%) were involved in small scale mining and about 72% of those involved in mining were into washing, which involves trapping of gold with mercury in the palm. Forty-seven percent and 29.4% had worked in small scale mining for 2.5years and 5-10years respectively whiles17.5% had worked in small scale mining. Most of the respondents (68.8%) worked with mercury and the majority burned amalgam or melted gold daily or at least once a week. About three fourth of the respondents put mercury in their palms without gloves during work and about 45% work with mercury daily.

Table 4.2 Habitat and work exposure of study respondents

Variables	Frequency	Percentage
How long living in this area (n=494)		
– ≤1year	53	10.7
– 2-5years	146	29.6
– >5years	295	59.7
Employed (n=487)		
– Yes	317	65.1
– No	170	34.9
Occupation (n=353)		
- Professional	7	2.0
- Clerical	-	
– Sales and services	24	6.8
– Small scale mining	236	66.9
– Agriculture	38	10.8
– Skilled manual	9	2.5
– Other unskilled manual	39	11.0
If small scale work description (n=406)		
– Washing	293	72.2
– Grinding	25	6.2
– Melting	20	4.9
– Pit work	68	16.7
Work duration with SSM		
– ≤1	26	6.1
– 2-5	201	47.0
– 5-10	126	29.4
– ≥10	75	17.5
Do you work with mercury (n=475)		
– Yes	327	68.8
– No	70	14.7

– Uncertain	78	16.4
How many times do you burn amalgam (n=381)		
-daily	122	32.0
-at least once a week	86	22.6
-at least once a month	36	9.4
-never	137	36.0
How many times do you melt gold (n=409)		
-daily	107	26.2
-at least once a week	123	30.1
-at least once a month	45	11.0
-never	134	32.8
How do you handle mercury? (n=432)		
-put in the palm without gloves	326	75.5
-put in palms with gloves	106	24.5
How do you handle amalgam? (n=320)		
-separating	22	6.9
-squeezing	192	60.0
-carrying	7	2.2
-opening	9	2.8
Any other way	90	28.1
How many times work with mercy (n=460)		
-daily	207	45.0
-at least once a week	116	25.2
-at least once a month	36	7.8
-never	101	22.0
Return with working clothes to your home (n=488)		
-yes	222	45.5
-no	266	54.5
Do you keep work clothes at home (n=492)		
-yes	223	45.3
-no	269	54.7

Source: Field data, 2019

4.3 Food and water consumption characteristics

Most (68%) of the respondents consumed fish daily and about 48% consumed locally produced chicken often. The majority also consumed eggs (63.5%), meat (64.8%) and fruits and vegetables (73%) often. The most cited source of drinking water was sachet water (53.2%) whereas pipe-borne water was the most cited source of cooking water (53.2). The sources of water for other household chores included borehole (45%) and pipe-borne water (45%).

Table 4.3 Food and water consumption

Variables	Frequency	Percentage
How frequently do you eat fish?		
– Daily	340	68.0
– At least once a week	107	21.4
– At least once in two weeks	24	4.8
– At least once a month	11	2.2
– Never	18	3.6
Do you consume from local production:		
Chicken		
– Never	34	6.9
– Occasionally	224	45.3
– Often	237	47.9
Ducks		
– Never	326	67.2
– Occasionally	136	28.0
– Often	23	4.7
Eggs		
– Never	15	3.1
– Occasionally	164	33.5
– Often	310	63.5
Meat (beef)		
– Never	24	5.0

– Occasionally	146	30.2
– Often	313	64.8
Vegetables, fruits		
– Never	7	1.4
– Occasionally	124	25.6
– Often	354	73.0
Milk		
– Never	57	11.6
– Occasionally	199	40.5
– Often	235	47.9
Household sources of water:		
Drinking (n=496)		
– Bore hole	88	17.7
– River/stream	14	2.8
– Pipe borne water	131	26.3
– Sachet water	256	53.2
Cooking		
– Bore hole	194	39.1
– River/stream	28	5.6
– Pipe borne water	264	53.2
– Sachet water	10	2.0
Other household chores		
– Bore hole	223	45.0
– River/stream	40	8.1
– Pipe borne water	223	45.0
– Sachet water	10	2.0

Source: Field data, 2019

4.4 Lifestyle, health conditions and past health problems

Figures 4.1 and 4.2, and Table 4.4 presents results of the lifestyle and disease prevalence among the respondents. The prevalence of malaria was 77% (Figure 4.1). As shown in

Figure 4.2, skin problems was the most reported health condition among the respondents (39.2%). This was followed by numbness in the palm and feet (34.2% and 33.8% respectively), respiratory problems (18.1%) and tremors (16.9%). The prevalence of anxiety and tuberculosis were 11.9% and 9.5% respectively whiles 11.1% stated that they had other conditions. Some of the other conditions named by respondents included Hypertension, eye problems, chest pains, waist pains, typhoid and migraine.

Figure 4.1: Prevalence of malaria

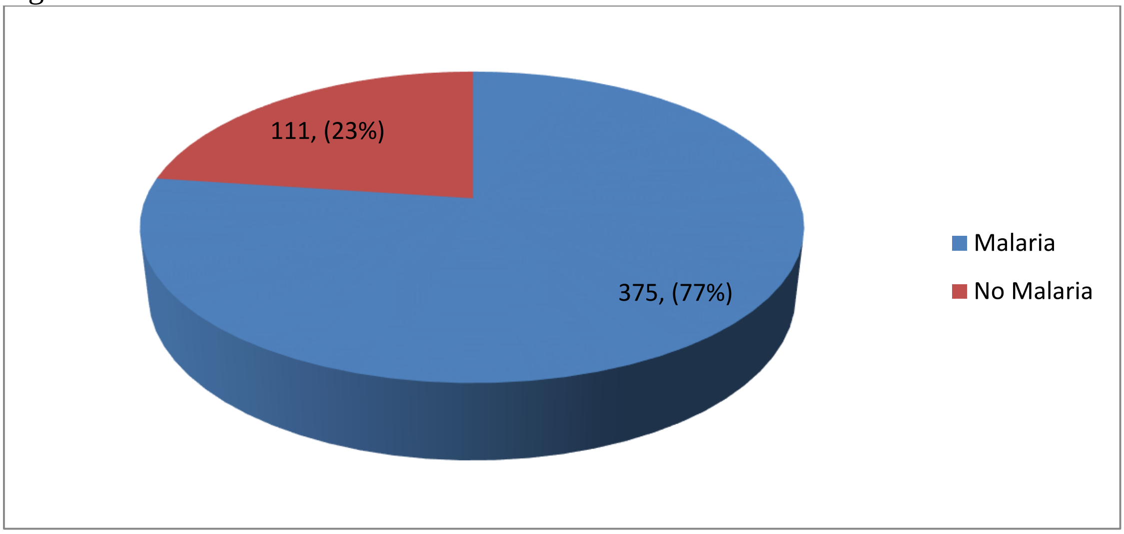
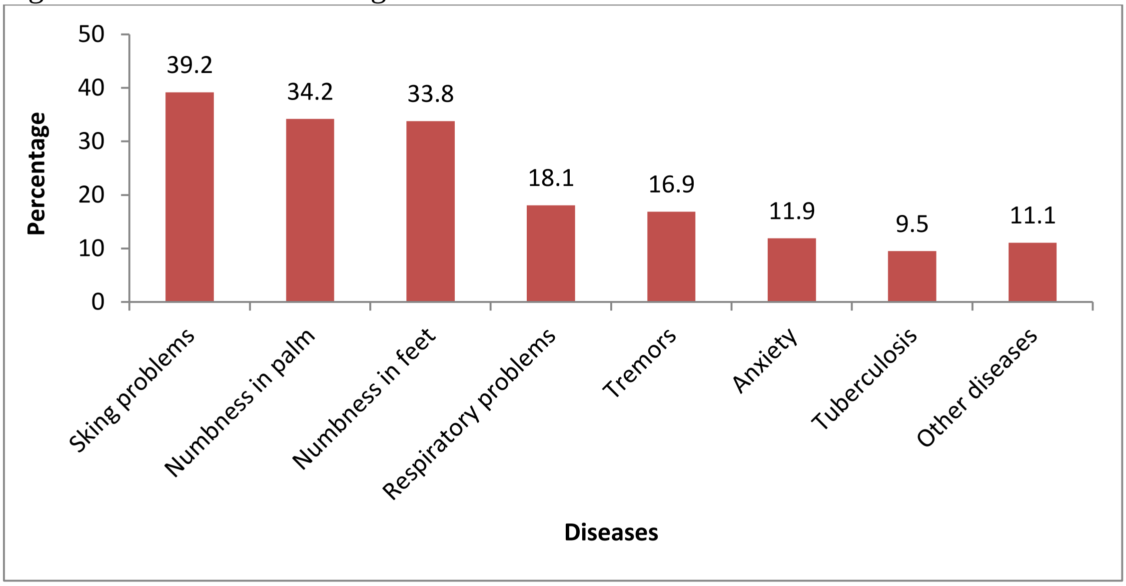


Figure 4.2: Prevalence of mining related diseases



As shown in Table 4.4, most of the participants disclosed that they were healthy (71%). About 4.8% of the respondents believed their health problems has worsened since their exposure to mercury. Seventy-six respondents constituting 15.3% were smokers and majority (63.9%) smoked 10-20 cigarettes per day. About 28% of the respondents drink alcohol with beer being the most consumed (70.5%). About 43.6% drink daily and out of 89 respondents, 39.4% drank 1-3 bottles of beer per day. About 27% suffered from excessive salivation. Majority of the respondents believed that with tremors, they have poor performance than usual at work. About 16% of respondents had sleeping problems at night and this was attributed to tiredness from work or unknown causes.

Table 4.4 Lifestyle and health status of respondents

Variable	Frequency	Percentage
Are you healthy now?		
-Yes	358	71.0
-No	146	29.0

Actual or former health problem worsened since exposure to mercury		
-Yes	21	4.8
-No	253	57.8
-Uncertain	117	26.7
-No mercury exposure	47	10.7
Do you smoke cigarettes?		
-Yes	76	15.3
-No	401	80.8
-Used to	19	3.8
If yes, how many?		
-lot(more than 20 cigarettes per day)	4	28.3
-medium(10-20 cigarettes per day)	19	63.9
-rarely (0-10 cigarettes per day)	66	7.9
Do you drink alcohol?		
-Yes	139	28.2
-No	315	63.9
-Used to	39	7.9
If yes what type (n=139)		
-beer	98	70.5
-wine	37	26.6
-spirit/ other hard drink	18	12.9
-local hard drink	62	44.6
How often do you drink? (n=149)		
-daily	65	43.6
-at least once a week	56	37.6
-at least once every two weeks	11	7.4
-at least once a month	17	11.4
1-3 bottles of beer (n=89)		
-Per day	35	39.4
-per week	54	59.6
>3 bottles of beer (n=31)		
-per day	10	32.3

-per week	21	67.7
1-3 glasses of wine		
-per day	3	14.3
-per week	18	85.7
>3 bottles of wine		
-per day	2	33.3
-per week	4	66.7
1-3 glasses of tuba		
-per day	24	46.2
-per week	28	53.8
>3 glasses of tuba		
-per day	12	37.5
-per week	20	62.5
Usually feel a kind of a metallic taste in your mouth2		
-Yes	79	16.3
-No	405	83.7
Do you suffer from excessive salivation?		
-Yes	131	27.0
-No	354	73.0
Do you have any problems with tremor (shaking) at work?		
-Yes	83	16.9
-No	409	83.1
How does tremor interfere with your work?		
-I have tremor or tremor interfere with my job	38	24.5
-I am able to do everything, but with errors; poorer than usual performance because of tremor	111	71.6
-I am unable to do any outside job; housework very limited	6	3.9
Do you have any problems with sleeping at night?		
-Yes	81	16.3

-No	417	83.7

Source: Field data, 2019

4.5 Association between work characteristics and work related diseases

Table 4.5 presents the association between working characteristics and mining related diseases (skin diseases and numbness). The kind of employment was associated with numbness (p=0.015) but not skin diseases (p=0.273). However, among small scale miners, the type of work was significantly associated with both skin diseases and numbness, with a higher prevalence among those involved in pit work and melting, p<0.001. The work duration of the small scale miners was also associated with skin diseases, with disease prevalence increasing with increasing duration of involvement in small scale mining (p<0.001). The prevalence of skin disease was also significantly higher among those who work with mercury (45%) as compared to those who do not work with mercury (31.4%), p<0.001. Similar association was observed between working with mercury and numbness. Working on mercury without gloves was also associated with higher prevalence of skin diseases (p<0.001) and numbness (p<0.001) as compared to those who wear gloves. The frequencies of melting gold (p<0.001) and handling mercury (p<0.001) were also associated with skin diseases, with higher prevalence observed among those who performed these tasks daily.

Table 4.5 Work characteristics and mining related diseases

Variables	Skin diseases		p-value	Numbness		p-value
	Present N (%)%	Absent N (%)%		Present N (%)%	Absent N (%)%	
Employment			0.273			0.015
• SSM	88 (38.1)	143 (61.9)		105 (44.5)	131 (55.5)	
• Agriculture	16 (42.1)	22 (57.9)		13 (34.2)	25 (65.8)	
• Other	42 (30.9)	94 (69.1)		41 (29.7	97 (70.3)	
If small scale work description			<0.001			<0.001
• Washing	43 (23.8)	138 (76.2)		62 (33.5)	123 (66.5)	
• Grinding	40 (42.6)	54 (57.4)		44 (46.3)	51 (53.7)	
• Melting	19 (51.4)	18 (48.6)		7 (18.9)	30 (81.1)	
• Pit work	68 (53.5)	59 (46.5)		66 (51.2)	63 (48.8)	
Work duration with SSM			<0.001			0.422
– ≤1	10 (20.0)	40 (80.0)		17 (33.3)	32 (66.7)	
– 2-5	61 (41.5)	66 (58.5)		62 (40.8)	90 (59.2)	
– 5-10	60 (34.5)	114 (65.5)		63 (36.0)	112 (64.0)	
– ≥10	42 (56.0)	33 (44.0)		34 (45.3)	41 (54.7)	
Do you work with mercury			<0.001			<0.001
• Yes	145 (45.0)	177 (55.0)		156 (47.7)	171 (52.3)	
• No	22 (31.4)	48 (68.6)		24 (34.3)	56 (65.7)	
• Uncertain	16 (21.1)	60 (78.9)		8 (10.3)	70 (89.7)	
How many times do you burn amalgam			0.022			0.003
• Daily	49 (48.8)	71 (59.2)		57 (46.7)	65 (53.3)	
• At least once a week	31 (37.3)	52 (62.7)		43 (50.0)	43 (50.0)	
• At least once a month	7 (20.0)	28 (80.0)		19 (27.8)	26 (72.2)	
• Never	36 (26.3)	101 (73.7)		41 (29.9)	96 (70.1)	
How many times do you melt gold			<0.001			0.019
• Daily	56 (53.3)	49 (46.7)		55 (51.4)	52 (48.6)	
• At least once a week	43 (36.1)	76 (63.9)		45 (36.6)	78 (63.4)	
• At least once a month	6 (13.6)	38 (84.6)		15 (33.3)	30 (66.7)	

• Never	38 (28.4)	96 (71.6)		44 (32.8)	90 (67.2)	
How do you handle mercury?			<0.001			<0.001
• Put in the palm without gloves	144 (44.9)	177 (55.1)		146 (44.8)	180 (55.2)	
• Put in palms with gloves	24 (22.9)	81 (77.1)		25 (23.6)	81 (76.4)	
How many times handle mercury			<0.001			<0.001
• Daily	97 (47.3)	108 (52.7)		87 (42.0)	120 (58.0)	
• At least once a week	52 (46.0)	61 (54.0)		60 (51.7)	56 (48.3)	
• At least once a month	8 (22.2)	28 (77.8)		13 (36.1)	23 (63.9)	
• Never	25 (25.3)	74 (74.7)		17 (16.8)	84 (83.2)	
Return with working clothes to your home			0.065			0.192
• Yes	75 (34.6)	142 (85.4)		78 (35.1)	144 (64.9)	
• No	113 (42.8)	151 (57.2)		109 (41.0)	157 (59.0)	
Do you keep work clothes at home			0.303			0.040
• Yes	79 (36.2)	139 (63.8)		74 (33.2)	149 (66.8)	
• No	109 (40.8)	158 (59.2)		114 (42.4)	155 (57.6)	

Source: Field data, 2019; SSM=small scale mining

Table 4.6 presents results of the association between selected exposure variables and numbness and skin diseases. Being involved in pit work was associated with higher odds of numbness as compared to those who are engaged in melting, after adjusting for age, education, and duration of work (AOR: 3.93; 95%CI: 1.57 -9.86). A year increase in the duration of working in small scale mining was also associated with 1.09 higher odds of skin diseases (AOR: 1.09; 95%CI: 1.05 -1.14). Working with mercury was also associated with 3.72 times higher odds of numbness (AOR: 3.72; 95%CI: 2.21 -6.27) and skin diseases (AOR: 2.49; 95%CI: 1.51 -4.10) as compared with those who did not work with mercury. Handling mercury without gloves and handling mercury daily are also associated with higher odds of numbness and skin diseases. The number of times one burns amalgam was also significantly associated with numbness and skin diseases. As compared to those who never burned amalgam, burning amalgam daily was associated with about two times higher odds of numbness (AOR: 1.99; 95%CI: 1.14 -3.49) and skin diseases (AOR: 2.01; 95%CI: 1.12 -3.59). Burning amalgam once a week was also associated with higher of numbness as compared to those who never burned amalgam.

Table 4.6 Logistic regression analysis of association between selected exposure variables and mining related diseases

	Numbness		Skin diseases	
Variables	**AOR [95% CI]**	**p-value**	**AOR [95% CI]**	**p-value**
Description of SSM (ref=melting)				
• Washing	2.05 [0.82-5.09]	0.124	0.48 [0.22-1.05]	0.068
• Grinding	2.62 [1.01-6.78]	0.048	0.77 [0.34-1.76]	0.535
• Pit work	3.93 [1.57-9.86]	0.003	1.36 [0.62-2.98]	0.441
Work duration with SSM	1.03 [0.99-6.27]	0.166	1.09 [1.05-1.14]	<0.001
Do you work with mercury (ref=no/uncertain)	3.72 [2.21-6.27]	<0.001	2.49 [1.51-4.10]	<0.001
How do you handle mercury? (ref=with gloves)				
• Put in the palm without gloves	2.18 [1.29-3.68]	0.004	2.40 [1.40-4.10]	0.001
How many times handle mercury (ref=never)				
• Daily	3.31 [1.72-6.36]	<0.001	2.88 [1.56-5.30]	0.001
• At least once a week	5.41 [2.70-10.86]	<0.001	2.74 [1.42-5.29]	0.003
• At least once a month	2.35 [0.87-6.33]	0.092	0.88 [0.31-2.55]	0.818
How many times burn amalgam (ref=never)				
• Daily	1.99 [1.14-3.49]	0.016	2.01 [1.12-3.59]	0.019

• At least once a week	2.47 [1.35-4.51]	0.003	1.72 [0.91-3.23]	0.093
• At least once a month	0.82 [0.30 -2.27]	0.702	0.73 [0.25-2.16]	0.567

Regression analysis are adjusted for age, education, and duration of work; AOR=adjusted odds ratios; SSM=small scale mining

CHAPTER FIVE

DISCUSSION

This chapter presents the discussions of major findings of the study. The discussions are outlined in line with the objectives of the study and are discussed in relation to relevant published studies in this and other settings.

5.1 Key findings

This study was conducted to assess the prevalence of mining related diseases in two mining communities in the Ashanti region (Jacobu in the Amansie-Central district and Konongo in the Asante-Akyem district) and one community in the Eastern region of Ghana (Kibi in the East Akim Municipal district). Findings of this study show a high prevalence of mining related diseases; skin problems 39.2%, numbness in the palm 34.2% and feet 33.8%, respiratory problems 18.1%, tremors (16.9%) and anxiety 11.9%. The prevalence of diseases among miners was significantly associated with use of activities related to small scale mining and use of mercury for mining activities.

5.2 Discussion of key findings

5.2.1 Prevalence of mining related diseases

This study found a high prevalence of mining related diseases in mining communities in the Ashanti and Eastern region of Ghana. This findings corroborates previous studies that found high prevalence of certain disease among miners and mining communities in Ghana (Akabzaa and Darimani, 2001; Awudi, 2002). This include previous study by Ayaaba et al (2017) among surface and underground miners in Tarkwa and Obuasi mines in Ghana which found prevalence of 47.6% for respiratory related conditions. There is therefore an urgent need to prepare the health system to handle these emerging conditions, as most health workers are more likely to diagnose numbness in the as symptom of type 2 diabetes.

The impact of mining activities on health and diseases, is however not limited to miners but also to surrounding communities and populations. In Ghana, high prevalence of mining certain disease conditions are have been reported among communities closer to mining areas in Ghana. A study that looked at the health impact of mining activities of AngloGold Ashanti on five surrounding communities in the Obuasi Municipality for instance found that a 17.7% and 27% prevalence of skin diseases and respiratory infections respectively (Yeboah, 2008). Two communities in that study, Anyimadokrom and Sanso reported prevalence of 26.6% and 24.3% of skin diseases respectively. The prevalence of skin diseases in that study were attributed to contamination of water bodies with chemicals which some residents are dependent on for water, food and other domestic purposes. The high occurrence of skin diseases at Anyimadokrom is due to its proximity to AngloGold Ashanti's Pompola treatment plant where chemicals such as arsenic (sulfur dioxide) are used (Yeboah, 2008).

The estimate of prevalence of mining related diseases in this study and other related studies might however suffer from under/over estimation due to the reliance on self-report. Ideally, a sensitive symptom questionnaire and a follow-up medical examination is the best choice for case finding among the worker population (Lenderink et al., 2012). Undertaking a detailed etiological studies of exposed populations in which disease outcomes can be studied in relation to risk factors at work and other potential causative factors is a much robust way to estimate the incidence and prevalence of work-related diseases. This type of studies are however hardly performed on such a scale that findings could represent an estimate of the prevalence of several work-related diseases among larger populations. Self-report provides an efficient and accepted means of assessing population characteristics, risk factors, and diseases. Self-reported diseases among workers is shown to provide valuable information on the presence of diseases and diseases like musculoskeletal and skin diseases are shown to have more precise estimates which are generalizable (Lenderink et al., 2012).

5.2.2 Association between use of mercury and mining related diseases

Findings of this study shows a significant influence of the use of mercury on skin diseases and tremors. The majority (68.8%) of the workers involved in this study used mercury in small scale mining activities. Use of mercury was associated with higher odds of tremors and skin diseases the prevalence of skin diseases increased with increasing frequency of use of mercury. Some respondents in this study reported having excessive salivation (27%) and other respondents disclosed that they usually feel a kind of metallic taste in their mouth (16.3%).

The impact of mercury exposure on health has been well established in previous studies. The association between exposure to mercury and skin diseases for instance has been reported in previous studies (Behnam and Al-Saleem, 1977; Boyd et al., 2000; Sun, Hu, Yuan, Zhang, and Lu, 2017). Findings of this study also corroborates two studies in Ghana that have reported skin rashes, metallic taste and complaints of numbness as predominant complications suggestive of mercury exposure (Afrifa, Essien-Baidoo, Ephraim, Nkrumah, and Dankyira, 2017; Mensah et al., 2016). The study by Mensah et al found complaints of numbness were significantly associated with mercury exposure among those who have previously worked at other small-scale gold mines (Mensah et al., 2016). Similarly, a pooled analysis on miners and community members from various artisanal small-scale gold mining areas in Philippines, Mongolia, Tanzania, Zimbabwe and Indonesia found tremors as a typical symptom of chronic metallic mercury intoxication (Bose-O'Reilly et al., 2017). Other symptoms observed in that study were coordination problems, excessive salivation and metallic taste (Bose-O'Reilly et al., 2017).

Inhaled mercury vapor can easily pass through the walls of alveoli and enter the bloodstream resulting in the body absorbing 80% of the inhaled amount, causing severe neurological, cardiovascular, or renal problems (Díaz, Muñoz-Guerrero, Palma-Parra, Becerra-Arias, and Fernández-Niño, 2018). According to the World Health Organization, elemental and methylmercury are toxic to the central and peripheral nervous systems (World Health Organization, 2017). The report also indicate that inhalation of mercury vapour can produce harmful effects on the nervous, digestive and immune systems, lungs and kidneys, and may be fatal. Further, the inorganic salts of mercury are corrosive to the eyes, skin, and may induce kidney toxicity if ingested (World Health Organization, 2017). Among workers exposed to elemental mercury in air of 20 µg/m3 or more for several years, mild, subclinical signs of central nervous toxicity are observed (World Health Organization, 2017). Mercury salts are generally irritants on the skin that cause dermatitis, discoloration of the nails, and corrosion of the mucous membranes, and may also cause corrosive burns (Park and Zheng, 2012). It is estimated that approximately 7% to 15% of doses of inorganic mercury compounds are absorbed in the gastrointestinal tract after ingestion (Xu, Suiko, Sakakibara, and Pai, 2002).

The occurrence of mercury in the environment reported to be as a result of its use in gold recovery process, where inorganic form of the metal is either washed into rivers or readily vaporized into the atmosphere. Small-scale artisanal mining is the main source of mercury emissions into the environment, and releases 1400 tons per year into water, air, and soil. In 2010, small scale mining contributed about 37% of the total anthropogenic emissions, and 24% in 2011 (Gerson, Driscoll, Hsu-Kim, and Bernhardt, 2018; Green, Lewis, Wozniak, Drevnick, and Thies, 2019). Another report estimated that 5 tons of mercury is released from small-scale mining operations each year in Ghana (Asklund and Eldvall, 2005). With the increasing exposure mercury through small scale mining, there is the need for urgent attention to control mercury exposure among artisanal miners. According to previous reports, approximately 10 to 15 million people mainly in countries in Africa, Asia, and South America are involved in the extraction of gold through artisanal small scale mining. Additionally, according to calculations by the Global Mercury Assessment, around 3 million women and children worked in the artisanal mining sector in 2013 (Gerson et al., 2018; UNEP, 2013).

5.2.3 Association between other work related exposures and mining related diseases

The health effects of mining and disease severity among people exposed to mining activities might depend however on the kind of activities carried out during mining and the duration of exposure to harmful chemical used in mining. The different processes of small scale mining, such as washing, melting, pit work and grinding for instance constitute difference exposures to mercury. Report from the WHO for instance implicated the inhalation of a vaporized form of elemental mercury during amalgam smelting as the main route of exposure to mercury among miners (World Health Organization., 2008).

Small scale mining in Ghana is associated with life-threatening risks at the mine site, including dynamite blasts, collapsing pits and shafts and falls near excavation sites. Small-scale gold mining operations mostly use mercury to separate the gold from other materials through mixing mercury with gold-containing materials and forming an amalgam. The process of trapping gold is however done with the hand, which exposes the miners to the toxicity of mercury. Findings from this study showed higher odds of tremors and skin diseases among miners who burn amalgam and handled gold daily and those who handled mercury without gloves. An increase duration of work in small scale mining was also associated with higher odds of skin diseases. These findings could be due to the higher levels of mercury exposure related to these activities of small scale mining. This is supported by the outcome of the pooled analysis on miners and community members from various artisanal small-scale gold mining areas in Philippines, Mongolia, Tanzania, Zimbabwe and Indonesia where mean mercury concentrations showed highest levels above threshold limits among amalgam burners as compared to other exposed subgroups (Bose-O'Reilly et al., 2017). In that study, 54% the highly-exposed group (amalgam burners) were diagnosed as being mercury-intoxicated compared to 0% within the control group.

Despite the life threatening activities involved in small scale mining and the use of hand in trapping gold, the use of gloves for protection was limited in this study. More than three-fourth of the respondents in this study (75.5%) put mercury in their palms without gloves. These poses a huge health risk to small scale miners in the study area in Ghana as a whole. It is suggested that inorganic mercury may be absorbed through the skin by the transport of mercury across the epidermis and via the sweat glands, sebaceous glands, and hair follicles (Chan, 2011). This study corroborates findings from other studies in Ghana that reported very use gloves and other personal protective equipment among small scale miners, including the study among small-scale gold miners in the Talensi-Nabdam District of Ghana's Upper East region where 70% never used any form of personal protective clothing (Paruchuri et al., 2010). Similarly, study in Wassa West District also reported that <13% of miners used personal protective clothing (Dorgbetor, 2005) and in the study among small scale miners in Prestea, the use of personal protection was reportedly low (Mensah et al., 2016). Findings of this study showed that the miners who did not use gloves had higher odds of tremors and skin diseases. Use of hand gloves during mining activities could there offer some protection against diseases related to mercy exposure among miners.

5.2.4 Strength and limitations

The major strength of this study is the sampling from three mining disctrics in Ghana to ensure representativesness. The use of cross-sectional design in this study however made it impossible to make causal inferences.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

This section presents the conclusion of the study based on the key findings and make recommendations for improving the health of small scale miners and surrounding communities in the country for improved public health.

6.1 Conclusion

In conclusion, this study found high prevalence of diseases related to mining activities including skin problems, numbness in the palm and feet (peripheral neuropathy), respiratory problems, tremors and anxiety. This could indicate an emergence of certain diseases in mining areas in Ghana. However, the healthcare system in these areas might not be adequately prepared for the emerging health problems in mining areas.

The use of mercury is associated with mining related diseases such as numbness and skin diseases among small scale miners, independent of age, gender and the duration of exposure. Peripheral neuropathy and skin diseases were significantly higher among those who use mercury in small scale miners in the Ashanti and Eastern regions of Ghana and the use of mercury resulted in higher odds of tremors and skin diseases.

Further more, the activities of small scale mining such as the melting of gold and use of amalgam are associated with mining related diseases. Increase duration of work in small scale mining is also associated with higher risk of peripheral neuropathy and skin related diseases among small scale miners in the Ashanti and Eastern regions of Ghana.

Finally, the use of personal gloves for protection is very limited among small scale miners. Not using hand gloves is associated with higher odds of numbness and skin diseases among miners in the Ashanti and Eastern regions of Ghana.

6.2 Recommendations

Based on the findings of the study, the following recommendations are made to improve the health of small scale miners in Ghana and other similar settings:

- This study found high prevalence of certain diseases among small scale miners in Ghana. The Ministry of Health, Ghana Health Service and other health stakeholders should conduct regular health screening among this worker population and surrounding communities to identify the emergence of diseases among these populations.

- The Ministry of Health, Ghana Health Service and other health stakeholders should also set up surveillance systems in mining areas in Ghana to proper track the emergence of certain diseases related to mining to avert possible healthcare hazards.

- The government agencies and other stakeholders responsible for regulation and control of mining in the country should embark on training of small scale miners on the health consequences of the use of mercury for mining activities.

- Small scale miners in the study area and other areas in Ghana should be educated on the health implications of the use of bare hands in trapping gold and for handling mercury in small scale mining activities.

- The use of etiological studies and follow-up medical examinations is further recommended to measure and assess disease prevalence and related risk factors in mining areas in Ghana to better inform preventive policies.

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APPENDIX A- STUDY QUESTIONNAIRE

Title: Emerging diseases associated with mining; a study of mining communities in Ghana

I kindly ask you to answer the following questions and statements. By doing so, you contribute to a better scientific understanding of the topic above. Information provided will be kept strictly confidential. Thank you.

Interviewer

Date of interview: ………………………………………………………………

Name of the interviewer: ....

1 Personal Data ID Number__________

1.1 Participant

1.1.1 Date of Birth…………………………Age: ……………………..

1.1.2 Sex: Male [ ] Female [ ]

1.1.3 Educational Status No formal education [ ] Primary education [ ] Junior Secondary [ ] Senior secondary [ ] Tertiary education [ ]

1.1.4 Monthly income (GHC) Below 500 [ ] 500-1000 [ ] 1001-1500 [ ] 1500 above [ ]

1.1.5 Marital status Single [ ] Married [ ] Separated [ ] Divorced [ ] Widowed [ ]

1.1.6 Number of children _________

1.1.7 How many children were born alive? _________

1.1.8 How many children died in the meantime? _________

1.1.9 At which age? Cause of death (if known)? _________

1.1.10 Do you have any children with birth defects?

Yes [ ]

No [ ]

1.1.10a Which birth defects?

………………………………………………………

………………………………………………………

1.1.13 Address ………………………………………………………........

2 General Questionnaire

2.1 Habitat

2.1.1 How long have you been living in this area? ______months ______ year(s)

2.1.2 Which community do you live in? .….

2.2 Work Exposure

2.2.1 Are you employed?

Yes [ ]

No [ ]

2.2.2 Description of occupation

Professional/ technical/managerial [ ]

Clerical [ ]

Sales and services [ ]

Small scale mining [ ]

Agriculture [ ]

Skilled manual [ ]

Other unskilled manual [ ]

2.2.3 If small scale mining, job description

Washing [ ]

Grinding [ ]

Melting [ ]

Pit work [ ]

2.2.4 How many years have you worked in Small scale mining? _________

2.2.5 Do you work with mercury **or with mercury polluted tailings?**

Yes [ ]

No [ ]

Uncertain [ ]

2.2.6 How many times do you burn amalgam in the open (for example in pans)?

Daily [ ]

At least once a week [ ]

At least once a month [ ]

Never [ ]

2.2.7 How many times do you melt gold in the open or with inadequate ·fume hoods?

Daily [ ]

At least once a week [ ]

At least once a month [ ]

Never [ ]

2.2.8 How do you handle mercury?

Put in palms without gloves [ ]

Put in palms with gloves [ ]

2.2.9. How do handle the amalgam?

Separating the amalgam from excess mercury by a washing operation [ ]

Squeezing the amalgam through a cloth [ ]

Carrying bags filled with tailings [ ]

Opening or emptying bags with tailings [ ]

Any other way [ ]

2.2.9 How many times do you handle mercury in the above mentioned way?

Daily [ ]

At least once a week [ ]

At least once a month [ ]

Never [ ]

2.2.10 Do you return with working clothes to your home?

Yes [ ]

No [ ]

2.2.11 Do you keep work clothes at home?

Yes [ ]

No [ ]

2.3 Diet Issues and sources of water for household

2.3.1 How frequently do you eat fish?

Daily [ ]

At least once a week [ ]

At least once in two weeks [ ]

At least once a month [ ]

Never [ ]

2.3.2 Do you consume from local production:

Chicken Never [ ] Occasionally [ ] Often [ ]

Ducks	Never [ ]	Occasionally [ ]	Often [ ]
Eggs	Never [ ]	Occasionally [ ]	Often [ ]
Meat (beef etc.}?	Never [ ]	Occasionally [ ]	Often [ ]
Vegetables, Fruits	Never [ ]	Occasionally [ ]	Often [ ]
Milk or milk products	Never [ ]	Occasionally [ ]	Often [ ]

2.3.3 What are your household sources of water?

Drinking Bore hole [ ] River/stream [ ] Pipe-borne water [ ]
Sachet water [ ]

Cooking Bore hole [ ] River/stream [ ] Pipe-borne water [ ]
Sachet water [ ]

Other household chores Bore hole [ ] River/stream [ ] Pipe-borne water [ ]
Sachet water [ ]

2.4 Health Problems

2.4.1 Did you ever have malaria?

Yes [ ]
No [ ]

2.4.3 Did you ever have any major acute or chronic health problems in the past?

Kidney diseases	Yes	[ ]	No	[ ]
Skin problems (allergies, loss of hair, eczema's}	Yes	[ ]	No	[ ]
Problems to get pregnant, become a father (fertility}	Yes	[ ]	No	[ ]
Respiratory problems (asthma, pneumonia)	Yes	[ ]	No	[ ]
Hepatic disorders (hepatitis)	Yes	[ ]	No	[ ]
Major infections, like tuberculosis	Yes	[ ]	No	[ ]
Neurological disorders (epilepsy, Parkinson etc.}	Yes	[ ]	No	[ ]
Any mental/ nervous disorders?	Yes	[ ]	No	[ ]
Anxiety problems?	Yes	[ ]	No	[ ]
Do you feel Numb in palm?	Yes	[ ]	No	[ ]
Do you feel Numb in feet?	Yes	[ ]	No	[ ]
Other diseases	Yes	[ ]	No	[ ]

If yes: ....

2.4.4 Are you healthy now?

Yes [ ]
No [ ]

If no: Which health problems, do you have?

…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………

2.4.5 Has the actual or former health problem worsened since exposure to mercury occurred?

Yes [ ]

No [ ]

Uncertain [ ]

No mercury exposure [ ]

2.4.6 Do you smoke cigarettes?

Yes [ ]

No [ ]

Used to [ ]

2.4.7 If yes, how many?

Lots (more than 20 cigarettes per day) [ ]

Medium (10-20 cigarettes per day) [ ]

Rarely (0-10 cigarettes per day) [ ]

2.4.8 Do you drink alcohol?

Yes [ ]

No [ ]

Used to [ ]

(IF NO, MOVE TO QUESTION 2.4.12)

2.4.9 If yes, what type and how many time?

Beer [ ]

Wine [ ]

Spirits/ other hard drink [ ]

Local hard drink [ ]

2.4.10 How often do you drink?

Daily [ ]

At least once a week [ ]

At least once every two weeks [ ]

At least once a month [ ]

2.4.11 Can you quantify how many glasses or bottles you drink per day/week?

1/2/3 bottles of beer	Per day	[ ]	Per week	[ ]
> 3 bottles of beer	Per day	[ ]	Per week	[ ]
1/2/3 glasses of wine	Per day	[ ]	Per week	[ ]
> 3 glasses of wine	Per day	[ ]	Per week	[ ]
1/2/3 glasses of tuba-tuba or hard drink	Per day	[ ]	Per week	[ ]
> 3 glasses of tuba-tuba or hard drink	Per day	[ ]	Per week	[ ]

2.4.12 Do you usually feel a kind of a metallic taste in your mouth?

Yes [ ]

No [ ]

2.4.13 Do you suffer from excessive salivation?

Yes [ ]

No [ ]

2.4.14 Do you have any problems with tremor (shaking?) at work?

Yes [ ]

No [ ]

2.4.15 How does tremor interfere with your work?

I have tremor or tremor interfere with my job [ ]

I am able to do everything, but with errors; poorer than usual performance because of tremor [ ]

I am unable to do any outside job; housework very limited [ ]

2.4.16 Do you have any problems with sleeping at night?

Yes [ ]

No [ ]

If yes, what problems do you have? ………………………………………………………

……………………………………………………………………………………………….

APPENDIX B - ETHICAL APPROVAL

GHANA HEALTH SERVICE ETHICS REVIEW COMMITTEE

In case of reply the number and date of this Letter should be quoted.

MyRef. GHS/RDD/ERC/Admin/App 19/171
Your Ref. No.

Research & Development Division
Ghana Health Service
P. O. Box MB 190
Accra
Tel: +233-302-681109
Fax + 233-302-685424
Email: ghserc@gmail.com
28th January, 2019

Kwasi Safo Boakye
University of Ghana
School of Public Health
P.O.Box LG 1191
Legon-Accra

The Ghana Health Service Ethics Review Committee has reviewed and given approval for the implementation of your Study Protocol.

GHS-ERC Number	**GHS-ERC012/12/18**
Project Title	Emerging Disease Associated with Mining: A Study of Mining Communities in Ghana
Approval Date	28th January, 2019
Expiry Date	27th January, 2020
GHS-ERC Decision	**Approved**

This approval requires the following from the Principal Investigator

- Submission of yearly progress report of the study to the Ethics Review Committee (ERC)
- Renewal of ethical approval if the study lasts for more than 12 months,
- Reporting of all serious adverse events related to this study to the ERC within three days verbally and seven days in writing.
- Submission of a final report after completion of the study
- Informing ERC if study cannot be implemented or is discontinued and reasons why
- Informing the ERC and your sponsor (where applicable) before any publication of the research findings.
- Please note that any modification of the study without ERC approval of the amendment is invalid.

The ERC may observe or cause to be observed procedures and records of the study during and after implementation.

Kindly quote the protocol identification number in all future correspondence in relation to this approved protocol

SIGNED...
DR. CYNTHIA BANNERMAN
(GHS-ERC CHAIRPERSON)

Cc: The Director, Research & Development Division, Ghana Health Service, Accra