KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

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DEPARTMENT OF MATERIALS ENGINEERING

EVALUATION OF SOME CAUSES AND PREVENTION OF ACCIDENTS ASSOCIATED WITH ARTISANAL AND SMALL-SCALE MINING (ASM) WITHIN ASANKRANGWA AND KENYASI ENVIRONS, GHANA

BY

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DECLARATION

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

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ABSTRACT

Sound health, safety and environmental management standards require hazard identification and risk assessments in order to institute measures to prevent accidents. In recent times, many accidents have been reported in some artisanal and small-scale mining (ASM) areas in Ghana, which have resulted in loss of lives. Since most people are involved in these mining operations for sustenance, it is essential to identify the potential causes of these accidents and prescribe solutions thereof. Ten (10) ASM sites in the Asankrangwa and Kenyasi areas were selected for this study. Field studies and observations methods were employed to identify potential risks associated with their operations and preventive measures recommended. It was observed that alluvial and deep mining techniques were mostly used by the ASM operators. Hard grounds are blasted and excavated using either rudimentary materials or sophisticated equipment. The following steps are employed in the beneficiation process namely: crushing and milling, sluicing, panning and then mercury amalgamation and finally, roasting to recover the gold. Each of the processing stages has a certain degree of risk associated with it. Noise levels and silica dust levels were also monitored to determine the extent of exposure. Land use was also monitored to check the extent of land degradation. The risks were assessed using the semi-quantitative risk assessment tool and the necessary risk control actions applied. Seven hazard types were identified during the initial risk assessment using a 5x5 risk matrix representing HIGH to EXTREME risk significance range of (11-17) to (18-25) respectively. After inception of recommended controls, all the seven hazard types were reduced to MEDIUM and LOW risk significance range of (6-10) and (1-5) respectively. Fifty percent (50%) of the study sites showed HIGH fatality rates with the potential fundamental causes of accidents determined as: Use of explosives > Surface excavation > shaft sinking > treatment and processing > Working underground > Working in poorly consolidated terrains > Making tunnels. The noise and silica dust levels were all above the recommended occupational exposure limit and lands are also degrading rapidly. Risk assessment is recommended as necessary requirement for starting ASM ventures.

DEDICATION

I humbly dedicate this work to the Almighty God, who has made this work fruitful.

To my beloved mother, Madam Theresa Bartels who has been my source of hope and inspiration in all these years. To my brother, John and Sisters Beatrice and Gladys for their immense support throughout my education.

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LIST OF ABBREVIATIONS AND ACRONYMS

ASM	Artisanal and Small-Scale Mining
EPA	Environmental Protection Agency
FMEA	Failure Modes and Effects Analysis
ILO	International Labour Organization
IOHSAD	Institute for Occupational Health and Safety and Development
ITDG	Intermediate Technology Development Group
NGOs	Non-Governmental Organizations
PMMC	Precious Minerals Marketing Corporation
PNDC	Provisional National Defense Council
PPE(s)	Personal Protective Equipment(s)

QRA	Quantitative Risk Assessment
RSI	Repetitive Stress Injury
UN	United Nations
UNIDO	United Nations Industrial Development Organization
MHSWR	Management of Health and Safety at Work Regulations
ACGIH	American Conference of Governmental Industrial Hygienist
OSHA	Occupational Safety and Health Administration
H&S	Health & Safety
OEL	Occupational Exposure Limit
EIA	Environmental Impact Assessments
PNDC	Provisional National Defense Council
TRIFR	Total Reportable Injury Frequency Rate
FIFR	Fatal Incident Frequency Rate
WHO	World Health Organization
SAP	Structural Adjustment Program
M/DAs	Municipal & Districts Assemblies
HSE	Health & Safety Executive
GMC	Ghana Minerals Commission
GCoM	Ghana Chamber of Mines
UK	United Kingdom
ASSM	Association of Small-Scale Miners
US	United States

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Artisanal and Small-scale Mining (ASM) in Ghana is over 2,000 years old, and has been a source of wealth for the sector practitioners. ASM refers to mining projects that are undertaken by individuals or small groups of about 9 to 10 persons. ASM activities are often operated using rudimentary or artisanal tools, and attracts relatively low levels of productivity and low capital investment (PNDC Law 218, 1989). ASM operations vary according to the deposit type and its geographical location (Ntibrey, 2001).

In Ghana, the main mining methods employed by artisanal and small-scale miners can be categorized as follows: 1) shallow alluvial deposits occurring up to 3 meters in depth, and often worked by manual means; 2) Deep alluvial deposits that are about 7 to 12 meters deep and involve significant amount of excavations to expose the auriferous horizons and may need a much more strenuous activity for preparation; 3) Hard rock mining to expose reefs that are located at deeper levels (Ntibrey, 2001). Hard rock mining involves the use of explosives for blasting, crushing and grinding with locally made crushing plants, mortars and pestles. Worked out materials are processed by sluicing to obtain the gold concentrate. The concentrate is then mixed with mercury to form a gold amalgam, followed by heating to separate the gold.

The risks associated with ASM activities could be very enormous, since many of the miners do not observe any safety measures to mitigate the impacts. This became exacerbated by the fact that, until 1988, ASM activities in Ghana were only governed by very weak or ineffective legislation(s), or rules. In an effort to regulate ASM activities, the government of Ghana, between 1988-2006, promulgated PNDC Law 218, PNDC Law 219 (Adjei et al. 2012), and the new Minerals and Mining Act 2006, (Act 703) to strengthen the legal regime that governs ASM operations. Minerals Commission, Environmental Protection Agency (EPA), Municipal and District Assemblies (M/DAs), National Security, the Judiciary among others administers these legislations.

Despite the above legislative frameworks, ASM activities have often been characterized by fatalities. For example, in 2010, at Dunkwa-On-Offin in the Central Region of Ghana, one hundred and twenty-four (124) people perished as the result of collapsed side walls of a local pit along the banks of the Offin River (Table 1.1). In another episode at Attaso, near Kotokuom in the Ashanti Region, about 12 operators were trapped, resulting in at least nine deaths (Daily Graphic, 2010). Vast farmlands are also being destroyed by the day, alongside air and water pollution.

Although there is growing awareness of ASM hazards related incidents, not much have been done to stop or minimize such occurrences. It is also anticipated that there may be several incidents that may have gone unreported; however, improved information on ASM challenges could probably provide a clue for managing the menace in society. A careful study is therefore necessary to investigate ASM operations in Ghana in order to reduce the accidents in society. This study therefore was initiated to identify the hazards that cause accidents, assess the risks and put in place measures to prevent the occurrence of accidents.

1.2 PROBLEM STATEMENT

The mining activities of some, if not all, ASM companies currently in Ghana, have been a subject of keen interest and intense debate by the populace, environmental pressure groups and some international agencies due to the negative environmental impact nationwide (Amedjoe and Gawu, 2013). Mining, irrespective of the scale of operation, has some degree of impact on the environment, health and safety of personnel. The extent of damage depends largely on the mining and processing methods being used. In most cases, they can be minimized through environmental permitting and monitoring by field officers. Illegal miners, on the other hand, are responsible for the most significant share of environmental damages and occupational injuries including fatalities in the sector. This is because, they do not comply with any relevant safety and environmental management plans.

In Ghana, environmental problems associated with the small-scale mining of precious minerals can be broadly grouped into three categories, thus impacts of the land, water bodies and the air. The small-scale miners in their attempts to remove the precious minerals from the earth destroy it by creating moonlike landscapes consisting of unstable piles of waste without reclaiming it. Water courses are being destroyed and chemicals such as mercury which is used in the amalgamation process are leached into the nearby streams and rivers. The blasting, excavation, haulage and crushing of the ore also creates large amount of dust which pollutes the air.

There are also other forms of physical, mechanical, chemical, psycho-social and biological hazards associated with ASM operations which typically affect the health and safety of the operating personnel. These invariably have resulted in the various accidents in the sector. Though a number of fatal, serious, moderate and minor injuries as well as potentially fatal occurrences (near misses) have been occurring, only few have been reported. This has led to unavailability of reliable data or official statistics about accidents or occupational diseases within the ASM sector in Ghana.

Table 1.1 shows reports of deaths of ASM workers caused by pit collapse, cave-ins and others.

Table 1.1: Some fatal injuries sustained by some ASM workers in Ghana.

Date	Description of event as reported in the media	No. of Casualties	Location	Source
9-Dec-09	18 illegal miners trapped	18	Dompoase, Ashanti Region	www.myjoyonline.com
17-07-10	Trapped to death	9	Ataso, Ashanti Region	Ghana News Agency
24-08-10	Pit collapse on illegal miners	17	Subriso Fante, Ashanti Region	www.myjoyonline.com
27-06-10	Trapped in pit	124	Dunkwa-On-offin, Central Region	Daily Graphic
12-06-11	Suffocation due to smoke from diesel powered engines.	2	Jacobu	Graphic Online
3-Dec-11	Miners trapped to death	5	Kenyasi, Brong Ahafo Region	www.myjoyonline.com
18-06-12	Kids drowned in galamsey pit	3	Akrokeri, Ashanti Region	Ghana News Agency
18-08-12	Torn rope causing miners to free fall into pit	5	Obuasi, Ashanti Region	GhanaToGhana.com
20-08-12	Trapped in pit	3	Obuasi, Ashanti Region	Ghana News Agency
23-12-12	Pit collapse due to pit instability	10	Subriso, Ashanti Region	Ghana News Agency
22-01-13	Flooding of galamsey pit leading to collapse	3	Prestea/Huni-Valley, Western Region	Vibe Ghana
14-04-13	17 confirmed dead in collapsed mine	17	Kyekyewere / Central Region	www.myjoyonline.com

Source: The various Ghanaian media as in column 5 of Table 1.1

The most recent disaster is the Kyekyewere incident on 14th April, 2013 where 17 galamsey operators were confirmed dead after a pit collapsed on them at Kyekyewere in the Central Region of Ghana. The locations where the ASM accidents occurred have been provided in Figure 1.1

Three hundred (300) people were reported dead in 2011 as a result of illegal smallscale gold mining activities, popularly called, 'galamsey' in Ghana alone (Aubynn, 2012). The data provided in Table 1.1 shows only fatal injuries; there was no mention of the permanent disabilities; moderate and minor injuries as well as those who may be suffering a chronic occupational illness as a result of exposure to chemical, physical or biological hazards. The sector, if it remains unchecked will cost the nation more than half of the revenue generated from it in terms of treating water, planting trees, treating diseases, managing disasters etc. Additionally, in terms of the human resources and loss of some plant and animal species can never be recovered (Adjei et al., 2012). The locations of the ASM sites described in Table 1.1 are indicated on the map as shown in Figure 1.1

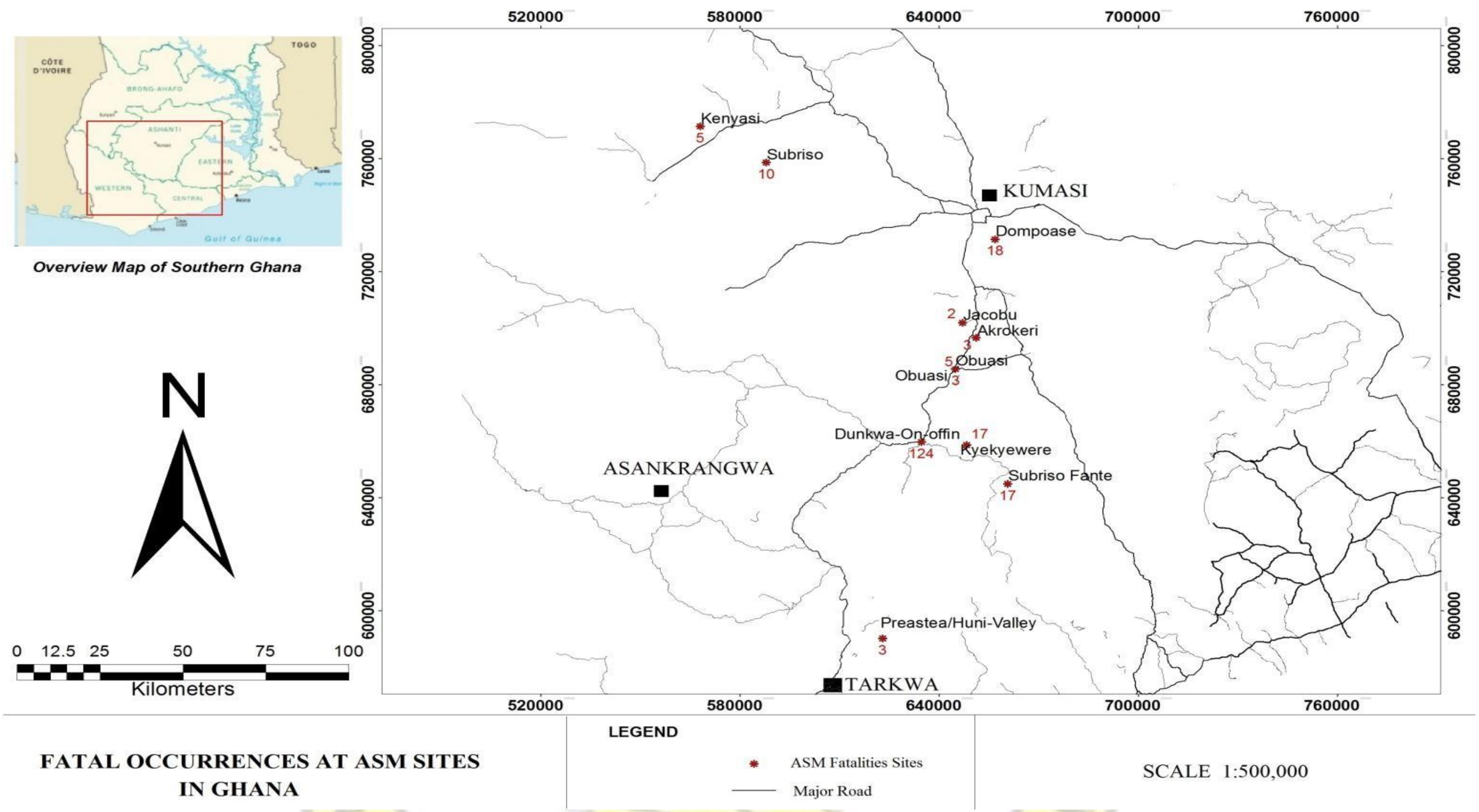

Figure 1.1 Locations of ASM fatal accidents reported in the Ghanaian social media in column 5 of Table 1.1

1.3 RESEARCH QUESTIONS

Key research questions to which answers would be sought include:

1. What are the main types and causes of accidents that occur at ASM sites?
2. How often do ASM accidents occur and do they get reported and investigated regularly?
3. What are the hazards and risks associated with the main ASM activities?
4. Are the ASM operators aware of the health and safety risks exposed to them?
5. How often do regulatory authorities visit ASM sites to check conformance to safety and environmental standards?
6. What safe work practices can be implemented by ASM operators to mitigate the risk associated with ASM operation?

1.4 OBJECTIVES OF THE STUDY

The general objective of this work is to identify the hazards that cause ASM accidents, and assess the health, safety and environmental risks and put in controls to prevent accidents.

The specific objectives of the research are to:

1. Determine the rate at which accidents (reportable injuries and fatal cases) occur in ASM establishments and how these accidents are managed.
2. Identify the hazards that cause ASM accidents and assess the risk posed by the significant ASM activities.
3. Implement control measures that are likely to prevent accidents based on the risk assessments.
4. Prioritize the hazards for management purposes in order to prevent possible future accidents.

1.5 JUSTIFICATION

The significance of this research work lies in the fact that it seeks to undertake a thorough outlook into the health, safety and environmental effects of artisanal small scale mining in the country. Additionally, the risks involved and the strategies to mitigate these risks to create safe working environment at the ASM sites would be assessed.

The outcome of the study may serve as a guide to the small-scale mining unions, NonGovernmental Organizations and the nation as a whole in formulating policies to combat the risks leading to fatal accidents in artisanal small-scale mining operation.

CHAPTER TWO

LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1 INTRODUCTION

Several research works have been conducted on ASM and its effects as well as contributions to economic development of countries endowed with mineral resources. These works focused on both the positive and negative impacts on the environment. This chapter gives the general overview of ASM, processes involved, and their associated risks at ore extraction. It also focused on the relationship between ASM and economic development as well as its impact.

2.2 HISTORICAL PERSPECTIVE

The Ghanaian ASM industry is well over 2,000 years old. Vestiges of alluvial gold extraction and winning activities were found as far back as the sixth century, and there is a wealth of evidence indicating that precious metals recovered from regional artisanal activities attracted Arab traders to certain areas of the country as early as the 7th and 8th centuries AD (Hilson, 2001). In fact, 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 labeled the 'Gold Coast' (Hilson, 2001).

Prior to 1989, ASM activities together with the marketing of gold resulting from their activities were considered illegal. Thus proceeds from their operations were smuggled to neighboring countries for sale. An estimated US$15 million worth of gold from illegal mining was smuggled out in 1985 to neighboring countries (Tetteh, 2011).

2.3 **DEFINITIONS, PROCESSES AND METHODS OF MINING**

2.3.1 Definition

ASM have been defined differently around the world. However, as the United Nations (UN) and Intermediate Technology Development Group (ITDG) definitions quoted below show, "small-scale mining" is generally defined in terms of a given production ceiling, or the level of sophistication with which minerals are exploited. ASM is any single unit mining operation having an annual production of unprocessed material of 50,000 tonnes, or less as measured at the entrance of the mine (United Nations, 1971). It is usually characterized as informal, illegal and unregulated by government, undercapitalized, utilizing simple tools and lacking in technology, and hazardous under labour intensive conditions. Additionally, artisanal and small-scale miners are "poor people; individuals or small groups who depend upon mining for sustenance (Aryee et al., 2003; Shoko, 2002) and those who use rudimentary tools such as picks, chisels, sluices and pans, and techniques to exploit their mineral deposits" (ITDG, 2001).

In Ghana, small-scale (gold) mining is defined as "mining (gold) by any method not involving substantial expenditure by an individual or group of persons not exceeding nine in number or by a co-operative society made up of ten or more persons" (PNDC Law 218, 1989) The definition therefore includes (1) what has been termed "artisanal" i.e. those operations using only rudimentary/artisanal implements, as well as (2) more sophisticated mining activities operating at a relatively low level of production and which generally require limited capital investment. It is important to clarify, however, that the more sophisticated small-scale mining concession holder/owner usually employs others and may even have contractors, some of whom may be expatriates, working for him (Aryee et, al. 2003).

2.3.2 Mining Methods

Mining methods employed by artisanal and small-scale miners of gold vary according to the type of deposit being exploited and its location. In view of the poor financial base of small-scale miners, a great majority of practitioners rely solely on traditional/manual methods of mining, which are largely artisanal, featuring simple equipment like shovels, pick-axes, pans, chisels and hammers (Ntibrey, 2001). The methods used in small-scale mining of gold in Ghana are categorized into the following three groups:

i. Shallow alluvial mining; ii.
   Deep alluvial mining; and iii.
   Hard rock (lode) mining.

Shallow alluvial mining techniques, which are popularly called "dig and wash" as seen in Figure 2.1, are used to mine shallow alluvial deposits usually found in valleys or low lying areas. Such deposits have depths not exceeding three (3) meters. Vegetation is initially cleared and the soil excavated until the gold-rich layer is reached. The mineralized material is removed and transported to nearby streams for sluicing to recover the gold. It should be noted that in view of the relative ease of reaching these deposits and treating such ores, a significant proportion of the industry's operations are of this type. For similar reasons, illegal workings are predominantly of this type (Aryee et, al. 2003).

Fig 2.1 Shallow alluvial mining

The deep alluvial mining techniques are used to mine deep alluvial deposits found along the banks of major rivers such as the Ankobra, Tano, Pra and Offin and certain older river courses. These methods involve excavating a pit and digging until the gold bearing gravel horizon, which is typically located at depths of 7 to 12 meters, is reached. Figure 2.2 shows a deep alluvial mining method with the terraces or benches constructed along the sides of pits to prevent collapse. The gold bearing gravel is then removed and sluiced to recover the gold (Aryee et al., 2003).

Fig 2.2 Deep alluvial mining

Hard rock mining techniques are adapted to mine gold bearing reefs, which can be located close to the surface or deep-seated. Holes are sunk to intercept the reefs and when accomplished, the reefs are worked along the strike. Where such reefs are weathered, small-scale miners use chisels and hammers to break ore. In cases where ore is hard, explosives are commonly used, despite the strict law regarding the use of explosives in Ghana (Aryee et al., 2003). Figure 2.3 shows a hard rock mining hole which is about 30m-40meters in depth.

Fig. 2.3 Hard rock (lode) mining

2.3.3 Processing Methods

Artisanal and small-scale gold miners invariably prefer free milling ores (not sulphidic ores), and therefore gravity concentration, using sluicing, is the main method for processing (Aryee et al., 2003). In the case of alluvial ores, the traditional ore processing method, which usually yields a recovery rate of approximately 60%, involves the sluicing of mined material in a sluice box to obtain gold concentrate. Mercury is added to the concentrate and mixed to form a gold amalgam, which is then heated to separate the gold (Aryee et al., 2003).

When processing hard rock ores, traditional or manual methods using artisanal implements are typically used. This is largely due to a lack of capital to purchase the requisite crushing and milling equipment to facilitate the process. The manual method of gold extraction from hard rock ore involves “pounding” (crushing and grinding) using locally designed metal mortars and pestles. In fact, the mortar and pestle have faded out of the system currently and has been replaced with locally made crushing plant. The resultant powder is mixed with water and sluiced to obtain a gold concentrate, which is later amalgamated with mercury (Aryee et al., 2003).

2.4 SOCIO-ECONOMIC IMPACT OF ARTISANAL AND SMALL-SCALE MINING IN GHANA

2.4.1 Employment

ASM is a significant source of income in many developing countries such as Papua New Guinea, Bolivia, Colombia, Indonesia, Mali, the Philippines, and Zimbabwe (Shoko, 2002). In the Philippines, small-scale mining has been the leading occupational group among all mineral industries (Caballero, 1996). According to Zubiri (2010), ASM plays an important role in the Philippines' local revenue and currently employs 300,000 miners. About 80% of the country's gold supply comes from small scale mining, making the country one of the top gold producers in the world.

Most ASM in Ghana are engaged in the business simply because they can generate wealth quickly. Although not capital intensive, small-scale mines require sufficient manpower; labour-intensive small-scale mining operations are economically feasible because investment costs per job are typically only 10–12 per cent as those costs in large mining operations (United Nations, 1992). ASM therefore, has a major impact on the employment situation in the developing world, especially in rural areas where there are few alternatives.

In a technical paper published by the World Bank entitled Strategy for African Mining it is estimated that some 30,000 people are employed within the legalized segment of the Ghanaian small-scale mining sector and still counting and that 60% of the country's mining labour force is, in fact, employed at small-scale mines. Regional employment assessments have also been made, most notably that of (Agyapong, 1998), who estimates that over 6,000 illegal and 117 registered artisanal gold mines are found in Tarkwa area alone. Over 1 million Ghanaians are involved in artisanal small scale mining. Ghanaian small scale mining sold 776,000 oz of gold valued at US$797.60 million (Tetteh, 2011).

2.5 **LEGAL FRAMEWORK FOR ASM IN GHANA**

The Ghanaian government, in 1989, established a legal framework within which artisanal and small-scale miners register and operate. The framework sought to streamline and facilitate the licensing and provision of technical support to such workings. It also among other things sought to provide an avenue for employment with a view to curbing rural-urban labour drift, absorb some of the excess labour who might have been retrenched as a result of the Structural Adjustment Programme (SAP), which was being implemented at the time. It also sought to monitor and supervise the activities of small-scale miners by ensuring acceptable mining practices with minimum damage to the environment and to stem the tide of encroachment of small-scale miners on large-scale concessions (Bawa, 2009).

Additionally, the Government of Ghana established the Precious Minerals Marketing Corporation (PMMC) in 1989 to provide a ready market for both gold and diamonds produced by artisanal and small-scale miners, through the promulgation of the Precious Minerals Marketing Corporation Law, PNDC L 219. The recent introduction of a jewelry manufacturing wing at PMMC has enabled the Corporation to manufacture jewelry for both local and export markets, thus further contributing to the success of the regularization scheme (Aryee et al., 2003).

In 2006, the legal regime of ASM was integrated into the new Minerals and Mining Act 2006, (Act 703). The Minerals and Mining Act, 2006 (Act 703) which is a continuation of the Small-Scale Gold Mining Law, PNDC L 218 enacted in 1989 giving the procedures of issuing a license to a small-scale firm. It is contained in Section 81 to 99 of the 1992 Constitution of the Republic of Ghana. Small-scale gold mining licenses may be granted to Ghanaians 18 years of age and older, and are subject to the following conditions:

i. A maximum allocation of 1.2 hectares of land in the case of a grant to any one person or group of persons not exceeding four in number; ii. A maximum allocation of 2.0 hectares of land in the case of a grant to any group of persons not exceeding nine in number; and iii. A maximum allocation of 10 hectares in the case of a grant to a cooperative society of 10 or more persons and registered companies.

Minerals Commission plays the lead role in the regulation of the ASM sub sector. Other collaborating agencies/organizations include: the Environmental Protection Agency (EPA), Municipal and District Assemblies (M/DAs), National Security, the Judiciary among others (Tetteh, 2011).

2.6 **IMPACTS OF ASM ACTIVITIES**

2.6.1 Environmental impacts

Mining, irrespective of the scale of operation, has some degree of impact on the environment (Aryee et al., 2003). The activities of ASM are causing serious environmental problems leading to the destruction of lands, rivers and streams and also air through pollution. For example, both alluvial and deep mining methods uncover the minerals by removing the overlying vegetation cover, rocks and other strata. Enormous quantities of the vegetation cover are gouged out, inverted and buried converting the natural terrain into raw, bare, lifeless spoil banks (Greenwood and Edwards, 1979). Greater portions of the vegetation cover in the mined areas lose their properties and are unable to be used for any other purpose (Charis, 1994). Water, a vital necessity of life is affected both in quality and quantity by activities of the galamsey operators.

In Ghana, contamination of surface and ground water bodies have particularly been experienced in gold mining communities (Davis *et al*., 1994), and gold mining in recent times has become unpopular as it is regarded as a significant source of mercury (Hg), lead (Pb) and other heavy metal contamination in the environment. Some of the activities responsible for the above are; ore transportation, smelting and refining, disposal of the tailings and waste waters around mines (Hilson, 2001; Hilson, 2002; Aryee *et al*., 2003; Essumang *et al*., 2007; Paruchuri *et al*., 2010). The principal environmental problems caused by small-scale mining activities are however noted to be mercury pollution from gold processing and land and water degradation (World Bank, 1995).

As is the case in most developing countries, mercury amalgamation technique is relied upon heavily as it is a cheap, dependable, portable operation for concentrating and extracting gold from low-grade ores. It is now well known, however, that the chemical, in sufficient quantities, poses a serious threat to human health and is deleterious to a wide-range of ecological entities. Once in the natural environment, mercury undergoes a change in speciation from an inorganic to a stable methylated state (MeHg) by non-ezymically and microbial action, and when ingested, eco-

toxicological effects result.

Research undertaken and reported by NRS Consultants (NSR, 1994) reveals that small-scale miners occupationally exposed to mercury, are, in fact, contaminated. Analysis of hair samples obtained from miners in Tarkwa and Accra shows a mean value of 7.4µg/g; it is recommended by the World Health Organization that the average weekly intake of mercury should be no more than 5µg/kg of body weight, of which no more than 3.3µg/kg should be MeHg.

Two (2) unpublished studies commissioned recently by United Nations Industrial Development Organization (UNIDO) confirm further that there is a mercury pollution problem, although with unknown dimensions within certain small-scale gold-mining regions in Ghana. The first involved analyzing hair, urine, blood and nail samples from 187 adults residing in an artisanal gold-mining community, some 40 per cent of whom claimed to have health problems. Clinical examinations identified 13 men as having slight neurological disorders (as a result of mercury overexposure), many gold washers having elevated concentrations of mercury in their bloodstreams, and that there is an exposure to mercury in the community through contaminated food (Rambaud et al, 2001).

The aim of the second study which was carried out in Dumasi in the Western Region of Ghana was to depict mercury environmental impacts prior to the introduction of plans for mercury recycling. Soil, sediments, fish, chicken, vegetables, surface water and groundwater were sampled in April 2000 in order to determine levels of mercury contamination. Results indicate that although surface water and groundwater feature mercury concentrations below World Health Organization's (WHO) standards, sediments are seriously polluted and fish are contaminated to the point where they should not be consumed (Babut et al, 2001).

The careless handling of mercury was witnessed during visits to the individual mine sites under study, as ASM workers were observed to be using mercury without appropriate respiratory or skin protection. For example, the ASM group working on Sikamenaso employs a number of locals, many of whom are children to pan gold by hand. Typically, mercury is added and mixed by hand without using gloves. More significantly, however, once the amalgamation process has finished, the ore is roasted in the open air over charcoal fires.

A second major environmental impact of ASM in Ghana is land degradation. More specifically, clearing vast tracts of forest; digging of trenches and the upturning of vegetation which in turn leaves land bare and exposed to agents of erosion as shown in Figure 2.4. Approximately 15,000 ha of land are potentially affected by small-scale mining activities (World Bank, 1995). It is quite common for prospective sites to be stripped bare of vegetation topsoil, and where deep underground mining has occurred, that pits are left uncovered and abandoned (Iddirisu and Tsikata, 1998). Agyapong (1998) who conducted fieldwork in the Western Region (Tarkwa) of Ghana, reports that vast tracts of the region have been deforested as a result of ASM

Artisanal mining activities have also scarred the landscape with 'excavated pits and trenches', which in turn render the 'land unsuitable for any other purpose'. Many of these pits have filled with water and serve as breeding grounds for malaria-infected mosquitoes. During personal visits to Asankran Breman and Asankra Saa in the Western Region, it was observed that resident small-scale gold mining operations have, in fact, caused a disproportionate amount of damage to land. Miners were seen to be working deposits on cliff tops as well as alluvial deposits within ponds and

rivers.

Fig 2.4 Upturn of vegetation leading to ponding and possible flooding and siltation.

Most of the underground operations are constructed haphazardly, excavated to unsafe depths and supported flimsily by logs and branches. Furthermore, in certain areas, huge patches of forest have been removed to establish quarters or ‘resting grounds’ for miners as depicted in Figure 2.5.

Fig 2.5 Miners 'ghetto'

In effect, ASM can cause adverse ecological impacts, such as unprotected abandoned sites, infertile farm land, damaged forests and various types of man-made pollution, in particular from electric batteries. Surprisingly, little has been done administratively to rectify these and related environmental problems. Checks from the EPA, Sunyani indicated that, environmental problems caused by illegal miners are only brought to their attention through the social media. In an attempt to implement policies for reclaiming small-scale mining sites, the Minerals Commission also introduced a Reclamation Fund, which called for a certain percentage of revenue from small-scale mining sales to be 'held' by the government and used to finance reclamation programs. As Davidson (1993), reports, between 1989 and 1991, $17,000 was contributed to the Land Reclamation Fund but communications with representatives from the Minerals

Commission have revealed that the initiative has long been abandoned, principally because of the challenges associated with extracting money from small-scale mining parties.

One of the prerequisites for securing a small-scale mining plot is completion of an Environmental Impact Assessment (EIA). In a highly discretionary procedure, the applicant identifies, generally, how he or she plans to address relevant environmental matters and the Minerals Commission, along with the EPA, use this information to determine whether or not the proposed initiatives are environmentally sufficient.

The main problem with this EIA procedure is that it does not target the specifics of environmental management, but rather asks vague environmental questions such as 'Give a brief overview of the likely environmental impacts of the mining activities?" and "Describe the mitigation measures proposed?" Certainly, with few environmental support programs in place for small-scale miners, mainly in the areas of technology and education, even if it were made a requirement that specific areas of environmental management be addressed in the environmental impact statement, it would be highly unlikely that proactive measures would ever be carried out by individual miners, who simply lack the finances and knowledge to undertake anything significant beyond the norm. (Hilson, 2002)

2.6.2 Health and Safety Impacts

The clandestine activities of ASM brings in its wake economic, environmental, health and social problems to the society and the country as a whole. The first point to consider is the human cost of artisanal and small-scale mining. A lot of lives have been lost through illegal mining. Many people have been buried in the earth due to collapsed pits, tunnels and workings. These openings are normally dug using primitive methods and are usually, weakly supported by timber. Mined out pits which are not filled abound in mining communities and are death traps to humans and animals.

2.6.2.1 Unsafe Work Practices and Behaviour

One of the most common occupational health and safety deficiencies in small scale mining is lack of awareness of the risks in mining coupled with lack of education and training (Henstschel et al., 2002). Women and children engaged in small scale mining in Congo were found exposed to various health risk factors such as poor hygiene, malnutrition, and difficulty of work (Hayes, 2009). The study also found that there was a high rate of miscarriages due to accidents and stress inherent in mining work.

In Papua New Guinea, Personal Protective Equipment (PPE) was never been used in small scale mining activities. The artisanal and small-scale miners purchase their own safety equipment such as helmet, boots, gloves, and face mask. Non-use of safety equipment is due to lack of awareness, lack of training, non-application of safety regulation, and illiteracy (Henstschel et al., 2002).

2.6.2.2 Occupational Hazards in Mines

One of the most popular issues in mining is non-compliance with occupational health safety standards. For example, many small-scale mining operations are said to be lacking in the following- safety regulations, reinforcement of mine safety requirements, awareness of the risks inherent in mining, and access to better equipment (Hentschel et. al., 2002). Risk factors lead to higher health risks and poorer working conditions in small scale mining compared to formal and large scale mining. In fact, the incidence of accidents in small-scale coal mining in Africa was found significantly higher than in large scale mines (Hentschel et al., 2002).

Exposure to dust is another common hazard among ASM workers and a source of health problem among ASM workers is dust (Chakravorty, 2001). This is high a risk to personnel involved particularly in ore crushing or working near ore crushers. Workers in Southwest India used towels to cover their face as a protection from the red dusts generated by spraying off the manganese. The dust, when inhaled, can cause lung diseases and other respiratory ailments. Exposure to dust can also cause skin irritation and impair vision (Bhagyalakshmi, 2007).

Since free crystalline silica is the most abundant element in the earth's crust, exposures to silica dust are quite prevalent in mining operations. Respirable silica dust is typically produced when drilling, blasting, or cutting silica-containing rock. When crystalline silica enters the lung, fibrotic nodules and scarring can occur around the trapped silica particles.

This fibrotic condition of the lung is called silicosis. If the nodules grow too large, breathing becomes difficult and death may result. Silicosis victims are also at high risk of developing active tuberculosis (Owen, et al, 2008).

Miners also suffer from musculoskeletal disorders such as back pain due to manual lifting of materials (Colina, 2006; Chakravorty, 2001). Sacks of waste materials as well as gold bearing ore are moved especially from underground pits to the surface by sequence of movements of the load from one person to the other. Findings of a study in and around small scale gold mining camps in Tanzania showed that workers handling mercury were highly at risk of mercury poisoning (Van Straaten, 2000). High levels of mercury in urine samples were detected among the eight amalgamation workers in Venezuela, and four workers showed symptoms of mercury poisoning such as nausea, stomach irritation, headache and behaviour changes. (Veiga et al., 2006).

2.7 Mine Accidents and Injuries

Mining is considered by International Labour Organization (ILO) as one of the most unsafe human activities. In the study of the Institute for Occupational Health and Safety and Development (IOHSAD) in the Philippines, the reported leading types of mine accident included the following; being hit by falling objects, suffocation from chemical fumes, and crushing injuries. Other occupational health hazards in mining include exposure to intense heat, poor ventilation, vibration, dust, fumes, Repetitive Stress Injury (RSI), intense noise, and biological hazards. In underground mining, poor ventilation causes respiratory failure that can cause brain malfunction or even death.

Most of the relevant causes of accidents among small scale miners are rock falls and subsidence, use of poorly maintained equipment, and non-compliance to wearing of proper protective equipment, and safety practices. Suffocation from diesel fumes drinking mercury contaminated water, use of explosives, flooding and being trapped or buried are among the most common accidents. In the Cordillera region, results of Mines & Geosciences Bureau - Cordillera Administrative Region (MGB-CAR) investigations showed that suffocation, drowning, falling, blasting, and rock fall were the most common causes of deaths in the region (Department of Environment and Natural Resources - Mines and Geosciences Bureau (DENR-MGB), 2011). The accident ratio study shows that for every major injury (resulting in fatality, disability, lost time or medical treatment), there are 10 minor injuries, 30 equipment damage and 600 Near Miss incidents (Bird and Germain, 1996). The accident ratio pyramid designed by Bird is shown in Figure 2.6

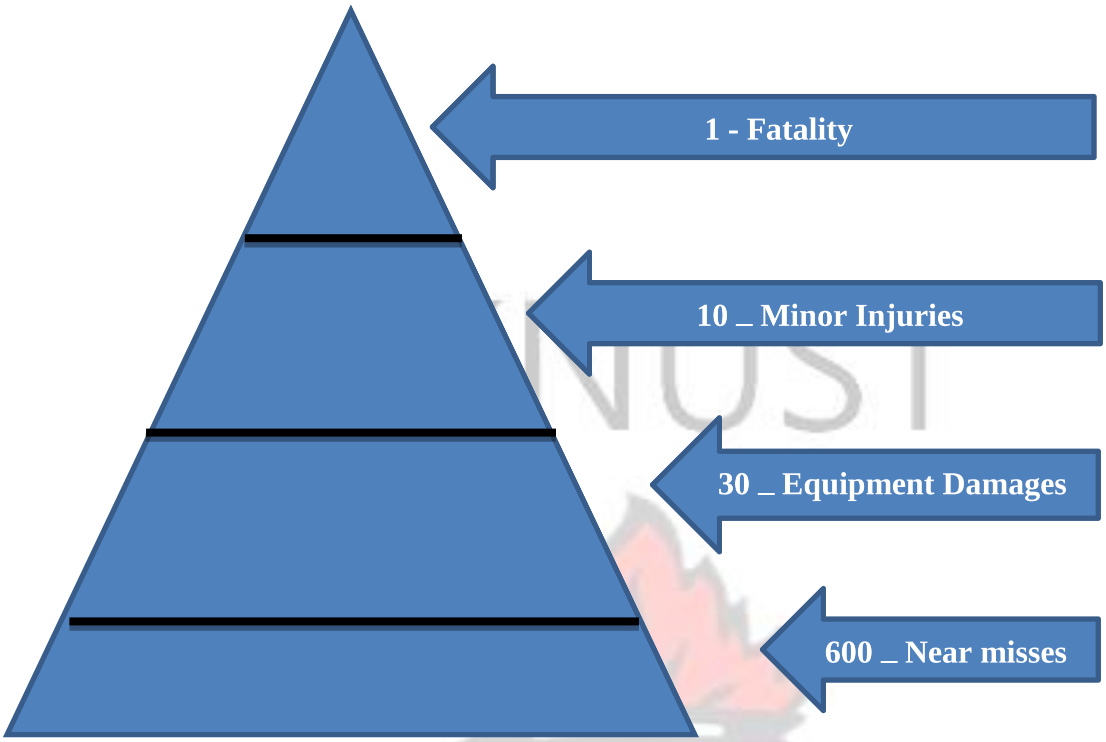

Fig 2.6 Frank Bird Accident Pyramid, (Bird and Germain, 1996).

The 1-10-30-600 relationships in the ratio in Fig 2.6 indicate clearly how unwise it is to direct major effort only at the relatively few events resulting in serious or disabling injury when there are so many significant opportunities that provide a much larger basis for more effective control of total accident losses. The significant point is that major injuries are rare events and that many opportunities are afforded by the more frequent, less serious events to take actions to prevent the major losses from occurring.

2.7.1 Total Recordable Injury Frequency Rate (TRIFR)

This is a measure of the rate of all workplace injuries other than minor injuries whereby first aid treatment is required (OSHA, 2009) normalized per 100 workers per year. The Total Recordable Injury Frequency Rate (TRIFR) is derived by multiplying the number of recordable injuries in a calendar year by 200,000. The 200,000 figure (in the formula) represents the number of man-hours 100 employees working 40 hours per week, 50 weeks per year and provides the standard basis for calculating accidence rates by industries (OSHA, 2009)

$$\textbf{TRIFR} = \frac{\text{Number of Reportable Injuries}}{\text{Total Man-hours}} \times 200,000 \quad \text{-------------------------- (1)}$$

Accident rates of various types are used throughout industry. The accident rates are indications only of past performance and are not indications of what will happen in the future performance of the company. Accident rates have been standardized, so that Occupational Safety & Health Administration (OSHA) and other regulatory agencies can compare statistically significant data, and determine where industries may need additional program assistance. OSHA uses the recordable accident rates to determine where different classifications of companies (manufacturing, food processing, textiles, mining, etc.) compare to each other with regard to past safety performance (USDepartment of Labour, OSHA). The formula for calculating incidence rates can be used for other variables such as cases involving fatalities and severity rates

2.7.2 Fatality Incident Frequency Rate (FIFR)

This is a measure of the rate of all work related fatalities normalized per 100 workers per year. The Fatality Incidence Frequency Rate (FIFR) is derived by substituting the total number of fatal cases into the formula for calculating the Total Reportable Injury Frequency Rate (TRIFR) as represented by equation (1).

$$\textbf{FIFR} = \frac{\text{Number of Fatal Accidents}}{\text{Total Man-hours}} \times 200,000 \quad \text{--------------------------------- (2)}$$

2.8 HAZARD IDENTIFICATION AND RISK ASSESSMENT

2.8.1 Overview

Risk assessment is defined as a structured science-based process to estimate the likelihood and severity of risk with attendant uncertainty (Coleman et al, 1999). Hence, risk is a function of the chance of an event occurring and the consequence. It systematically examines all aspects of work that considers:

- what could cause injury or harm
- whether the hazards could be eliminated and if not,
- what preventive or protective measures are, or should be put in place to control the risks.

In the United Kingdom, risk assessment is a legal requirement under the Management of Health and Safety at Work Regulations 1992. Regulation 3(1) of the UK's 'Management of Health and Safety at Work Regulations 1992 states that,

'Every Employer shall make a suitable and sufficient assessment of;

a) The risks to the health and safety of his employees to which they are exposed whilst they are at work.

b) The risks to the health and safety of persons not in his employment arising out of or in connection with the conduct by him or his undertaking.

The Ghana minerals and mining Act 2006 sets a general health and safety duty for a holder of a small-scale mining license which includes a provision of work environment that do not expose workers to hazards. There is also a provision to conduct risk assessments in processing plants that use cyanide for gold recovery. There is however no clear-cut provision for a risk assessment in small-scale mining operation that uses mercury for gold extraction even though mercury has both acute and chronic health effects that can be fatal.

Generally, a hazard is anything that may cause harm, such as chemicals, electricity, working from ladders, machinery, blasting and working under suspended load to people, or damage to equipment, buildings or the environment. Risk is the chance that somebody could be harmed by hazards, together with an indication of how serious the harm could be (consequence).

Mathematically,

Risk = Likelihood x Consequence

2.8.1.1 Likelihood

The likelihood on the horizontal axis is estimated on the basis of historical evidence or experience that such consequence has materialized within the industry. It is the likelihood of estimated consequence occurring. It is also measured on a scale of 1-5 to indicate increasing probability of an event occurrence as depicted in the likelihood Table 2.1.

Table 2.1 Likelihood

Level	Description	Criteria (read as either/or)
5	Certain	The event is expected to occur in the most circumstances
		Risk has more than a 75% chance of occurring
		The event will occur within the next six months
4	Likely	The event will probably occur in most circumstances
		Risk has more than a 50-74% chance of occurring
		The event occur within 18months
3	Possible	The event could occur at some time
		Risk has 25-49% chance of occurring
2	Unlikely	The event is unlikely to occur
		Risk has less than 25% chance of occurring
		Will occur within 48months
1	Rare	Likelihood criteria (Occurrence of Event)
		will occur;

Source: (Bass, 2010).

2.8.1.2 Consequence

A scale of consequence from ‘1’ to ‘5’ is used to indicate increasing severity. The potential consequences rather than the actual ones are used, however, in some presentations, both are used. These can be thought of as the consequences that could have resulted from the hazard if things went out of control. A typical 5x5 consequence Table is as shown in Table 2.2.

2.2: The consequence

Table

Rating	Estimated Cost	Health & Safety	Environmental	Community	Operational	Security	Legal Compliance
1	Insignificant > $1,000	First Aid Injury Nuisance value	No or very low environmental impact Impact confined to small area	Isolated complaint No media enquiry	Loss equivalent to 1 hour of production interruption Routine wear and tear of screen panels at crusher requires change out.	Infractions: Violations of internal policies and procedures No personal injury of property damage	Minor technical/legal compliance issue unlikely to attract a regulatory response
2	Minor > $10,000	Medical Treatment Injury Restricted Work Injury	Low environmental impact Rapid cleanup by site staff and/or contractors Impact contained to area currently impacted by operations	Small numbers of sporadic complaints Local media enquiries	Loss equivalent to 6 hours of production interruption Metal tooth on loader bucket comes loose while feeding crusher. Crusher plugged and tooth has to be cut out of crusher.	Minor Criminal Offenses Example: Trespassing, Theft under $5000.00, Minor Property Damage, etc.	Technical/legal compliance issue which may attract a low level administrative response from regulator Incident requires reporting in routine reports (e.g. monthly)
3	Moderate > $100,000	Single Lost Time Injury	Moderate impact Cleanup by site staff and/or contractors Impact confined within lease boundary	Serious rate of complaints, repeated complaints from the same area Increased local media interest	Loss equivalent to 12 hours of production interruption The pressure oxidation vessel develops a small leak in the brick liner.	Appreciable property damage Theft over $10,000.00 value Low intensity civil unrest	Breach of regulation with possible penalties Continuing occurrences of minor breaches Incident requires immediate (within 48 hours) notification.
4	Major > $1,000,000	Multiple Lost Time Injuries Admission to intensive care unit or equivalent Serious, chronic, long term effects	Major environmental impact Considerable cleanup effort required using site and external resources. Impact may extend beyond the lease boundary.	Increasing rate of complaints, repeated complaints from the same area Increased local/ national media interest	Loss equivalent to 3-7 days of production interruption Equipment for gas cleaning at the roaster facility fails and requires replacement. Ground fall at the open pit closes of access road and buries equipment.	Significant property damage resulting in shut downs Significant Criminal offenses committed against persons. High intensity civil unrest High level fraud	Major breach of regulation resulting in investigation by regulator Prosecution, penalties or other action likely
5	Catastrophic >$10,000,000	Fatality(s) or permanent disability	Severe impact Local species destruction and likely long recovery period Extensive cleanup involving external resources Impact on a regional scale	High level of concern or interest from local community National and/or international media interest	Loss equivalent to more than a week of production interruption Pressure oxidation vessel fails and depressurizes Ground fall at an underground heading causes loss of entire heading.	Major criminal offenses Multiple fatalities Forced evacuation of all personnel	Serious breach of regulation resulting in investigation by regulator Operation suspended, licenses revoked.

Source; Newmont Ghana Limited (2012)

2.8.1.3 Risk Matrix

A risk matrix is a simple graphical tool that provides a process for combining:

- The Likelihood for an occurrence of an event (usually an estimate) and
- The consequence if the event occurred (usually an estimate)
- The likelihood and the consequence are marched together on a risk matrix chart as depicted in Table 2.3

2.3: Semi-Quantitative Risk Matrix

Table

RISK INDEX MATRIX	**Consequence Rating**				
Likelihood Rating	**1**	**2**	**3**	**4**	**5**
	Insignificant	**Minor**	**Moderate**	**Major**	**Catastrophic**
5 Certain	Low 5	Medium 10	High 15	Extreme 20	Extreme 25
4 Likely	Low 4	Medium 8	High 12	High 16	Extreme 20
3 Possible	Low 3	Medium 6	Medium 9	High 12	High 15
2 Unlikely	Low 2	Low 4	Medium 6	Medium 8	Medium 10
1 Rare	Low 1	Low 2	Low 3	Low 4	Low 5
Index Significance Priority		LOW (1-5)	MEDIUM (6-10)	HIGH (11-17)	EXTREME (18-25)

Source: (Anon, 2007)

2.8.1.4 Risk Ranking Guidance

Estimation of likelihood and consequence is not an exact science. The consequence estimates are based on anticipated scenarios of what ‘might happen’ and the likelihood estimates are based on historical information that such scenario has happened under similar conditions, knowing fully well that circumstances will never be exactly the same.

2.8.1 Types of Risk Assessments

2.8.1.1 Qualitative Risk Analysis

Table

This is a relative measure of risk based on ranking or separation into descriptive categories such as low, medium, high; not important, important, very important; or on a scale from 1 to 5. Where the hazards presented by the undertaking are few or simple, for example in many small businesses, it is appropriate to just carry out a simple qualitative risk assessment. This can be a very straightforward process based on informed judgment and reference to appropriate guidance. Where the hazards and risks are obvious they can be addressed directly, and no complicated process or skills will be required (MHSWR, 1999).

2.8.1.2 Semi-quantitative risk assessment

In many intermediate cases where the hazards are neither few and simple, nor numerous and complex, for example if there are some hazards that require specialist knowledge, such as a particular complex process or technique, it may be appropriate to supplement the simple qualitative approach with a semi-quantitative assessment. In carrying out semi-quantitative risk assessments, simple qualitative techniques, supplemented by for example measurements to identify the presence of hazards from chemicals or machinery, or the use of simple modeling techniques may be appropriate. Simple modeling techniques may be used to derive order of magnitude estimates of the severity of the consequences and likelihood of realization of hazards. These estimates can be combined to obtain estimates of the order of magnitude of the risk.

A number of different techniques for carrying out semi-quantitative risk assessments exist, including risk matrix approaches (Worsell and Wilday, 1997; Middleton and Franks, 2001) and lines of defense/layers of protection analysis (Franks, 2001).

2.8.1.3 Quantitative Risk Analysis (QRA).

This involves obtaining a numerical estimate of the risk from a quantitative consideration of event probabilities and consequences. In carrying out quantitative risk assessments, special quantitative tools and techniques must be used for hazard identification, and to estimate the severity of the consequences and the likelihood of realization of the hazards. Where such methods and techniques are used it is important that they are carried out by suitably qualified and experienced assessors. The results of the QRA will be numerical estimates of the risk, which can be compared to numerical risk criteria at the risk evaluation stage. (MHSWR, 1999).

2.8.2 General Risk Assessment Steps

The Health & Safety Executives (HSE), United Kingdom (UK) (HSE, 2014),

identified 5 main steps in hazard identification including 1: Look for the hazards 2: Decide who might be harmed and how. 3: Evaluate the risks and decide whether the existing precautions are adequate or whether more should be done 4: Record your findings 5: Review your assessment and revise it if necessary. There are also other processes, though five steps but do not follow exactly what has been described above by the HSE, UK. Generally, risk assessments steps involve:

Step 1. Identify Hazards

Step 2. Assess the Risks

- Assess the Likelihood & Consequences
- Classify the Risk

Step 3. Control the Risks

- The hierarchy of risk control can be used as a guide

Step 4. Record Findings

Step 5. Monitor / Review Control Measures

Risk assessments should be reviewed on regular basis or when there is any reason to suspect they may no longer be valid. For example: following an accident, incident or near-miss; as significant new information becomes available; or when there have been significant changes to working procedures. Such reviews are unplanned reviews that should be triggered by significant changes. Other information of relevance to the validity of risk assessments and assumptions within them will come from monitoring by way of inspection and from routine measurements, e.g. air quality measurements and medical surveillance (Holt, 1999).

2.9 HEALTH, SAFETY AND ENVIRONMENTAL MANAGEMENT

2.9.1 Health, Safety and Environmental Policy

The health, safety and environmental policy of an organization provide guidance on how the health, safety and environment would be managed and implemented across the whole organization. A typical ASM will therefore set up a policy that will demonstrate its commitment to delivering its service in a safe and environmentally friendly manner by:

- Complying with current legislation and other requirements as applicable
- Implementing and continually improving the effectiveness of the health, safety and environmental policy and procedures
- Providing documented health and safety arrangements and safe systems of work which are communicated to all employees with the intent of preventing injury and environmental incidents
- Setting and reviewing health & safety objectives and targets to drive continual improvement.

- Monitoring health and safety performance to clarify whether continual improvement has been achieved and to enable resources to prioritize areas of under achievement
- Consulting with employees to ascertain their issues relating to health, safety and environment
- All persons fulfilling a management positions including Directors, are required to maintain high standards of health, safety and environment throughout their areas of responsibility

This policy statement must be signed by the senior person to demonstrate leadership commitment and reviewed periodically.

CHAPTER THREE

METHODOLOGY

3.1 STUDY AREAS

This chapter covers the background and profile of the Asutifi and the Wassa Amenfi West District Assemblies of the Brong Ahafo and the Western regions of Ghana respectively.

3.2 GENERAL DESCRIPTION OF STUDY AREA

Asankrangwa is a town with a population of about 15,000 in the Western Region of Ghana. It is located on 562670E and 641235N. The surrounding communities where the study was conducted are as shown on the map in Figure 3.1.

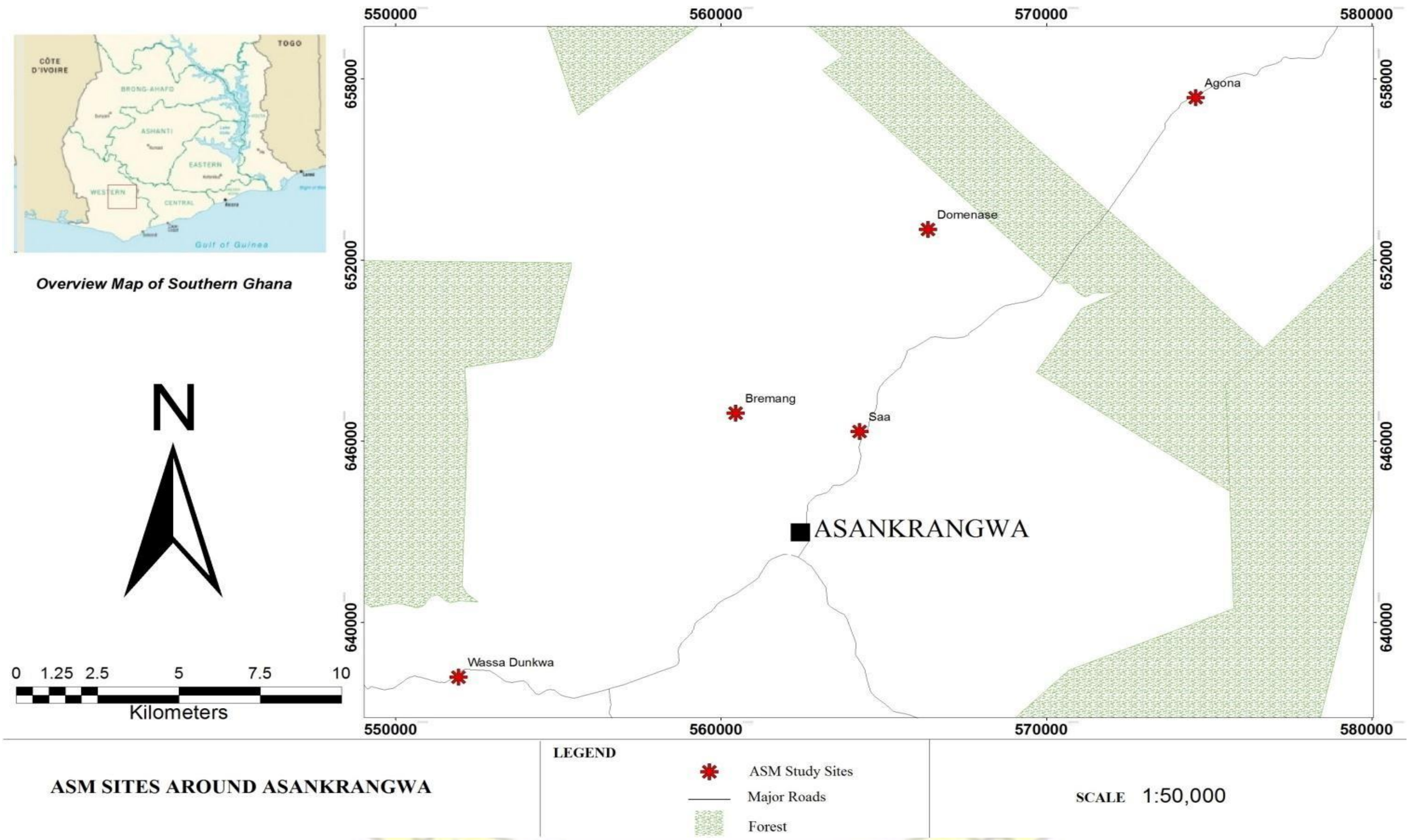

Figure 3.1 Asankrangwa area map showing the five (5) ASM study sites.

The current population of the Wassa Amenfi West District is projected at 186,257 at a growth rate of 3.2% per annum which is the region’s growth rate (National Population and Housing Survey, 2000).

The Wassa Amenfi West District is located on the Birimian rock system; the district lies within the Kumasi Basin and partly within the Sefwi Gold belt, however a major part of the district is positioned in the transitional zone of Sefwi and the AximKonongo gold belts. The Asankrangwa-Manso-Nkwanta belt features as a prominent fault which has gold potential. The rock type also provides mineralization for bauxite, manganese, and iron-ore deposits. The Opon Mansi iron ore deposit features as an economic asset for the district. It is currently being re-evaluated to provide economic exploitation for interested investors. Alluvial gold deposits occur in the Tano River basin within the district; however the policy on ASM does not encourage gold dredging, due to the implied environmental concerns.

Kenyasi is the capital of Asutifi District in the Brong Ahafo Region with coordinates, 568161E and 771314N. The community lies within the forest dissected plateau physiographic region which is underlain by Precambrian rocks of Birimian (known to be the gold bearing rocks and also have a high potential for manganese and bauxite) and Dahomeyan formation (Adjei et al, 2012). The study sites are indicated on the map in Figure 3.2.

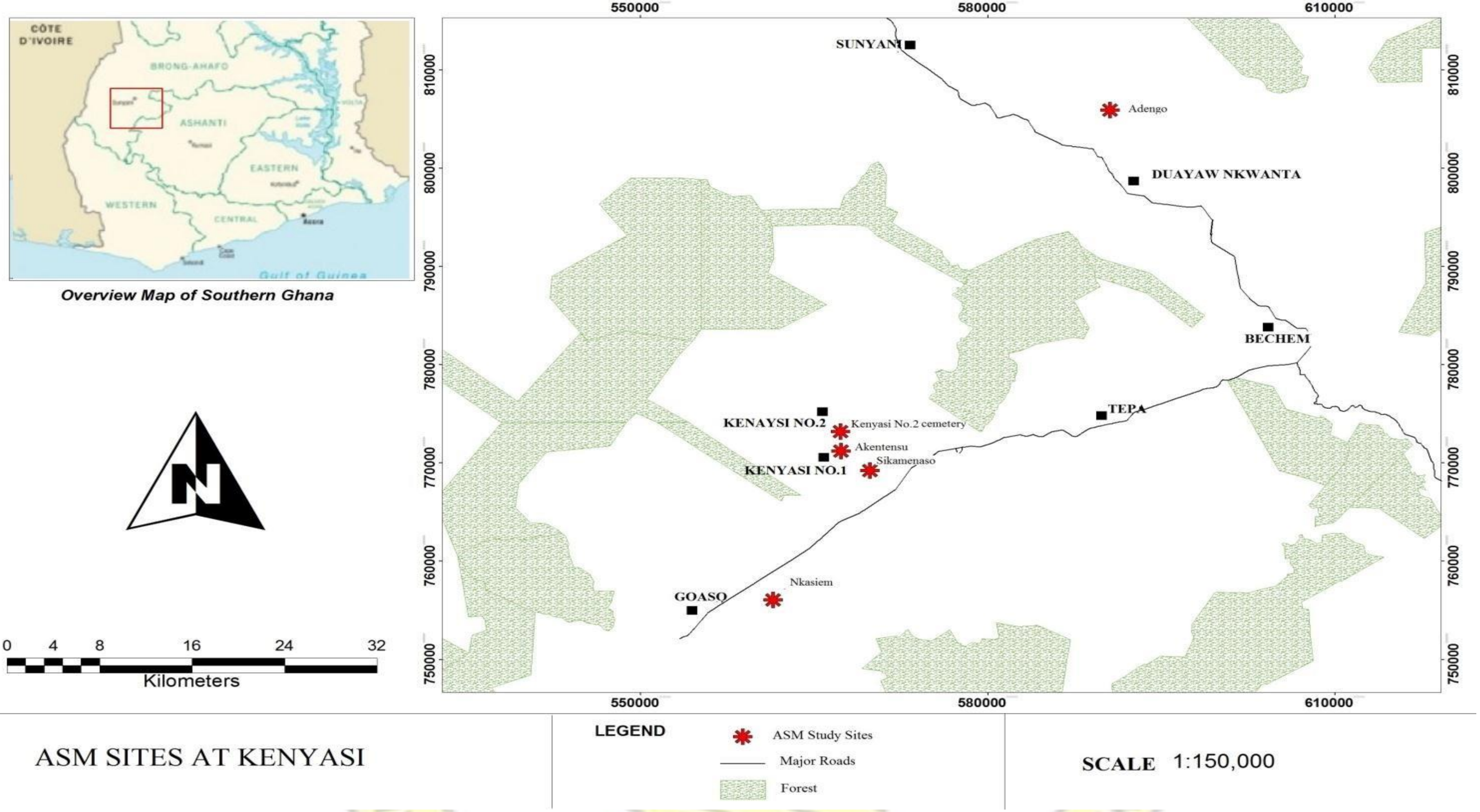

Figure 3.2 Kenyasi area map showing the five (5) ASM study sites.

In the Kenyasi area, gold is currently being mined by Newmont Ghana Gold Limited and galamsey operators. The community is divided into two parts, Kenyasi No.1 and Kenyasi No.2. The population of Kenyasi was about 11,050 with Kenyasi No.1 having 3,599 people and Kenyasi No.2, 7,451 people in 2000 (National Population and Housing Survey, 2000). Active galamsey sites exist in other communities surrounding the Kenyasi Township.

3.3 DATA COLLECTION

3.3.1 Types of Data

Data collected included respondents' awareness, perception and general knowledge of hazards and risks of various mining methods as well as environmental considerations employed by the ASMs within the galamsey communities. Views of ASM workers on ASM accidents and the safety equipment as well as controls available to the workers in the ASM sites were also sampled and analyzed. Inquest cases associated with ASM activities from the Ghana Police Service were also taken as part of data gathering process. Similarly, data on the overall organization and operation of ASMs operations were collected and analyzed. Data on activities of agencies and organizations such as the Environmental Protection Agency (EPA), the Ghana Minerals Commission (GMC) and the Ghana Chamber of Mines (GCoM) were also collected.

3.3.2 Sources of Data and Methods of Data Collection

Data for this study were collected from primary and secondary sources. Primary data included administration of questionnaires to ASM workers in the field, ASM workers union i.e. Association of Small Scale Miners (ASSM) and other stakeholders. In addition, interviews were conducted with officials of the Minerals Commission as well as other government officials from the Ghana Police Service, the Environmental

Protection Agency and the District assemblies. Field observations were made to identify the various processes, materials, work practices and mode of operation of equipment at the ASM sites. Secondary data were collected from books, relevant articles from journals and reports of researches conducted on artisanal small scale mining operations in Ghana, other African countries and the world at large. Data were also collected from the Environmental Protection Agency, Minerals Commission, Ghana and Ghana Chamber of Mines and other publications relevant to this study.

3.4 SAMPLING DESIGN

In this study, media reports of ASM accidents were recorded. The methods of sampling were a combination of simple random, stratified and purposive sampling. The reason for this was that the data included different variables of the target population in terms of size of mine site and differences in specific tasks undertaken in the small scale mining activities. In all, there were about one hundred and forty five (145) artisanal and small scale mining sites of different sizes around the two (2) ASM communities under study. This includes those sites that are worked on very short term basis known as 'hit and run' types. Five (5) sites each were chosen from Kenyasi and Asankrangwa based on their relative mine site sizes, legal status, mode of operation and their geographical location.

Twenty five (25) respondents were sampled for questionnaire administration at each ASM site based on their specific roles in the organization of ASM in Ghana. This brings the total number of respondents to two-hundred and fifty (250). Respondents were randomly selected for the administration of a detailed questionnaire and ensuring a hundred percent completion rate. The justification of the sample size lies in the fact that time and resources available to the researcher were not enough to cover the entire number of workers in all the small scale mining sites within the environs of the two study areas. Since the five (5) ASM sites chosen for this survey were not concentrated at one area but were scattered across the main ASM community under study, the views gathered from the total sample of two hundred and fifty (250) respondents effectively represented the views of the entire population. Table 3.1 and

Table 3.2 give details of the sampling sites. **Table 3.1. Sampling Sites for Kenyasi Study Area**

Site Name	GPS coordinates		No. of pits	Estimated no. of operators	Status (Registered / Unregistered)	Comments
	X_UTM	Y_UTM				
Sikamenaso	769,209	569,857.514	450	5200	Unregistered	Over 500 foreign nationals
Nkasiem	756,036.2	561,456.427	632	7000	Registered	Over 600 foreign nationals
Akentensu	771,191.4	567,322.759	130	6100	Registered	Over 100 foreign nationals
Adengo	805,916	590,608.3	101	1700	Unregistered	
Kenyasi No.2 cemetery	773,184.5	567,314.296	20	400	Unregistered	

Source: Field data collection, May 2013.

Table 3.2 Sampling sites for Asankrangwa Study Area

Site Name	GPS coordinates		No. of pits	Estimated no. of operators	Status (Registered / Unregistered)	Comments
	X_UTM	Y_UTM				
Saa	645,794	564,800	120	3800	Unregistered	
Agona	659,459	576,206	38	5400	Registered	Over 50 foreign nationals
Wassa Dunkwa	638,259	651,524	744	7300	Registered	
Domenase	660,181	576,823	51	3300	Registered	Over 100 foreign nationals
Bremang	646,915	561,005	323	1200	Unregistered	Over 210 foreign nationals

Source: Field data collection, May 2013

Samples were taken at random from all five ASM sites at each study location and the mode of selection was based on special roles the respondents play in the business with respect to the following category:

Member of site committee group – This group belongs to those leaders on site and they are responsible for ensuring fairness, equity of general peacemakers as well as point of contact to gain concession in the mine site.

Alluvial miners group – Refers to those personnel who are heavily involved in or have practiced shallow mining.

Deep mining group on the other hand refers to those involved in or have practiced deep mining operation.

Ore processing/fitting group – Refers to those who are specifically involved in the general processing of the ore from crushing to gold recovery as well as those involved in maintenance of equipment at the site.

Traders group – Refers to those whose main task is mostly serving as porters for the miners and also supplying food, drink, tools and equipment, as well as sexual services. Women and children were predominant in this category.

3.5 Noise Exposure Monitoring using a Sound Level Meter

The level of noise emanating from the crushing plant from the ASM operations was measured using a noise dosimeter shown in Figure 3.3.

Fig 3.3 Noise dosimeter

The measurement was done to ascertain if the noise levels exposed to workers exceeded the Occupational Exposure Limit (OEL). The procedure below was followed during the measurements.

- The sound level meter was pre-calibrated according to manufactures directions.
- The meter was set up at the crushing plant and started.
- The meter recorded the noise produced by the crushing activity for eight hours
- The meter readings were recorded.

3.6 Silica Dust Exposure Monitoring

Silica dust from the crushing operations at the ASM sites were determined using a personal sampling pump connected to Tygon tubing and attached to a worker's collar. The other end of the Tygon tubing was connected to the PVC pre-weighed cassette and a 10-mm nylon cyclone. The pump was calibrated and set up as shown in Figure 3.3.

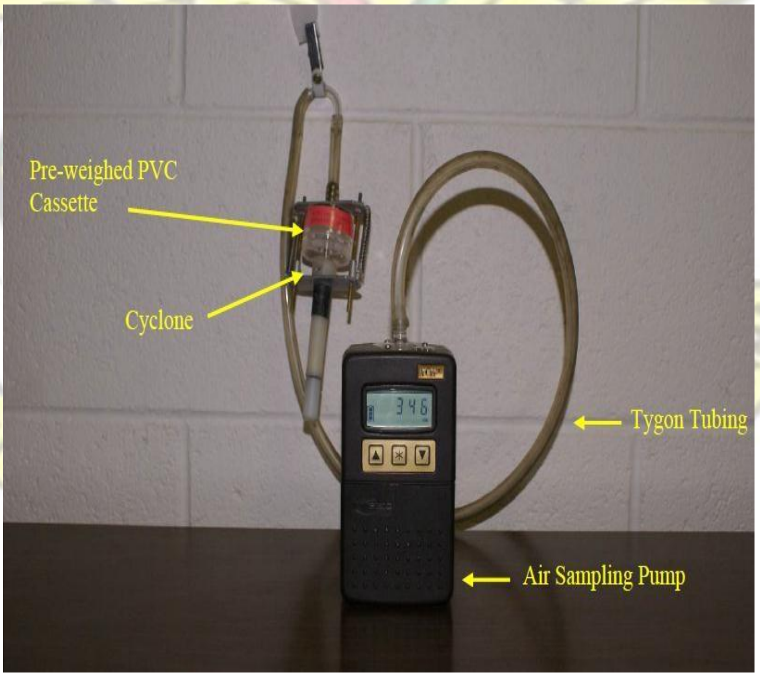

Fig. 3.4 Sample train for silica dust sampling. Train consists of air pump precalibrated to 1.7 Litres per Minutes, Tygon tubing, 10-mm nylon cyclone and pre-weighed PVC cassette.

The samples were collected and sent to the Bureau Veritas Laboratory in the United States for analyses.

3.7 Degraded Land Monitoring

The total mined-out areas at the small-scale mining sites that have been left unattended were measured to determine the extent of degradation with respect to ASM operations.

3.8 DATA ANALYSIS

Data collected were presented in the following categories;

i. Awareness of hazards and risks ii. Use of personal protective Equipment iii. Site monitoring to check conformance to regulations iv. Accident Frequency (Qualitative)

v. Accident Reporting vi. Fatal Incident cases vii. Accident causal factors viii. Dust Monitoring ix. Noise Monitoring

x. Land Use monitoring

Risk Analysis was performed on the significant activities of ASM using quantitative risk assessment approach and risk mitigation measures drawn.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 RESPONDENTS ABOUT RISKS OF AWARENESS

The awareness level of respondents regarding risk associated with ASM activities are presented in Figure 4.1. The data indicated that, as much as 179 respondents representing about 72% were not aware of the hazards and risks posed by ASM activities; about 21% were aware while about 7% had no idea.

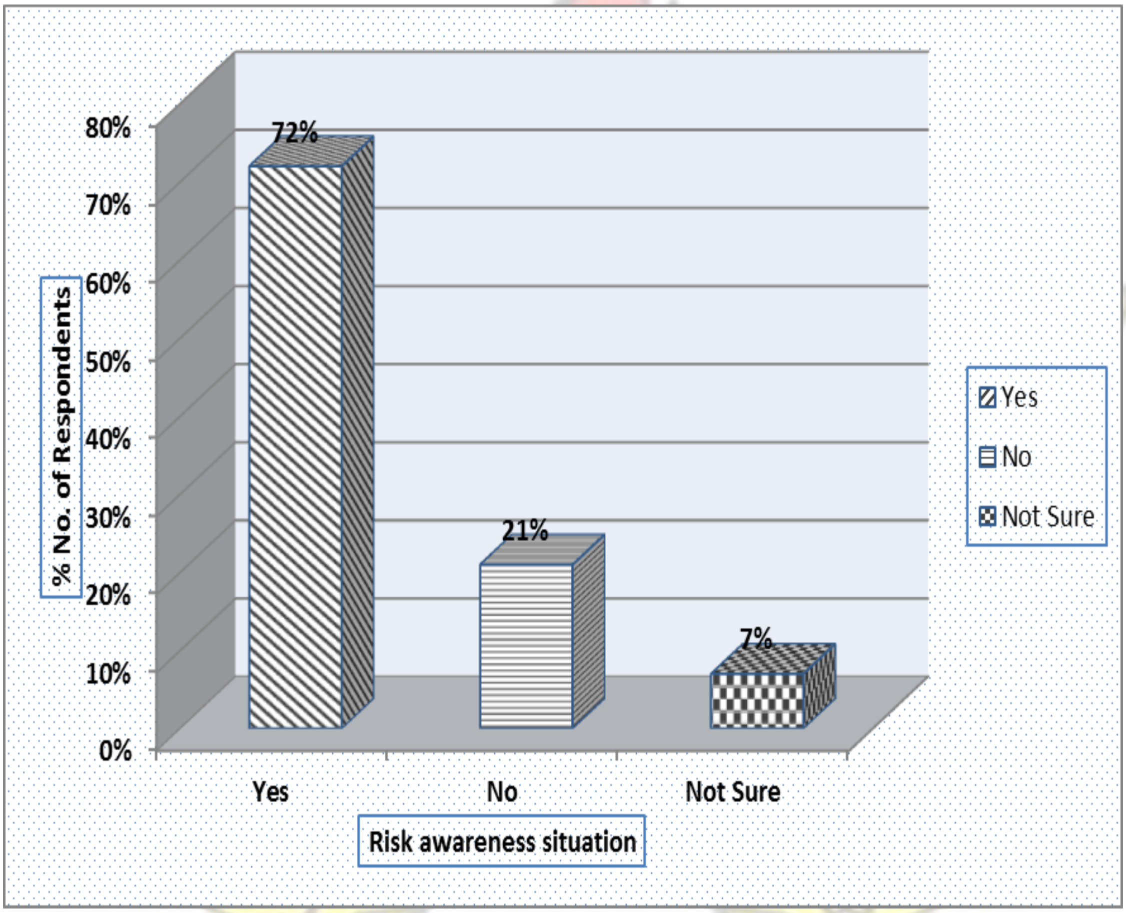

Figure 4.1: Awareness of hazards and risks associated with ASM activities.

4.2 USE OF PERSONAL PROTECTIVE EQUIPMENT (PPE) IN ASM

Data on the use of PPEs among ASMs are presented in Figure 4.2 below. It can be inferred that, only 4% of the respondents responded positive to Personal Protective Equipment (PPEs) usage at ASM sites, while as much as 90% did not; 6% had no idea about PPEs. From all the ten (10) sites visited, only few people were seen around the Kenyasi sites wearing some worn out safety boots. Some of the respondents upon interview blamed their inability to use the protective equipment to high cost of purchase. Others were not aware of the importance of wearing the protective device. According to some of those who were wearing the safety boots, they were received as gifts from their friends in the formal mining company within the vicinity. Other protective gear including, hard hats, safety goggles, dust masks, ear plugs and hand gloves were not seen at all during the survey.

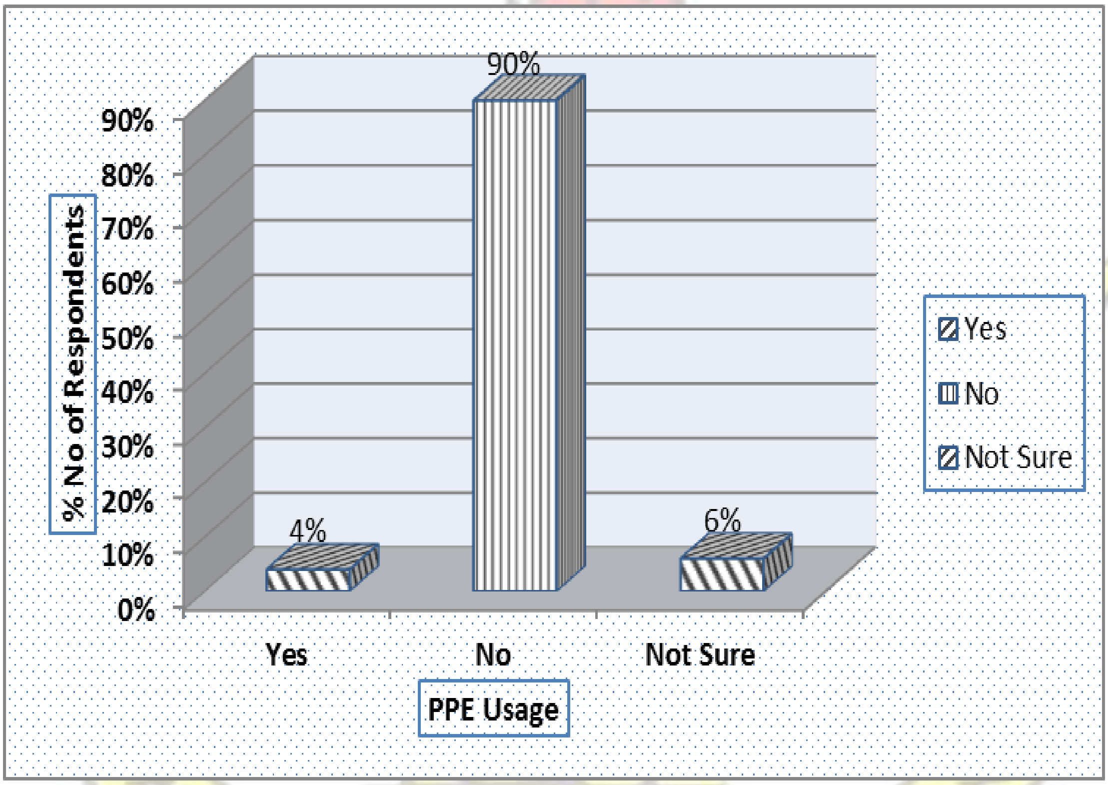

Figure 4.2: Use of Personal Protective Equipment in ASM

4.3 FIELD MONITORING BY REGULATORY OFFICERS

Figure 4.3 compared visits by regulatory authorities to both registered and unregistered sites. Clearly, the registered sites were visited regularly by regulatory authorities than the unregistered mine sites, due to the illegality associated with the

later.

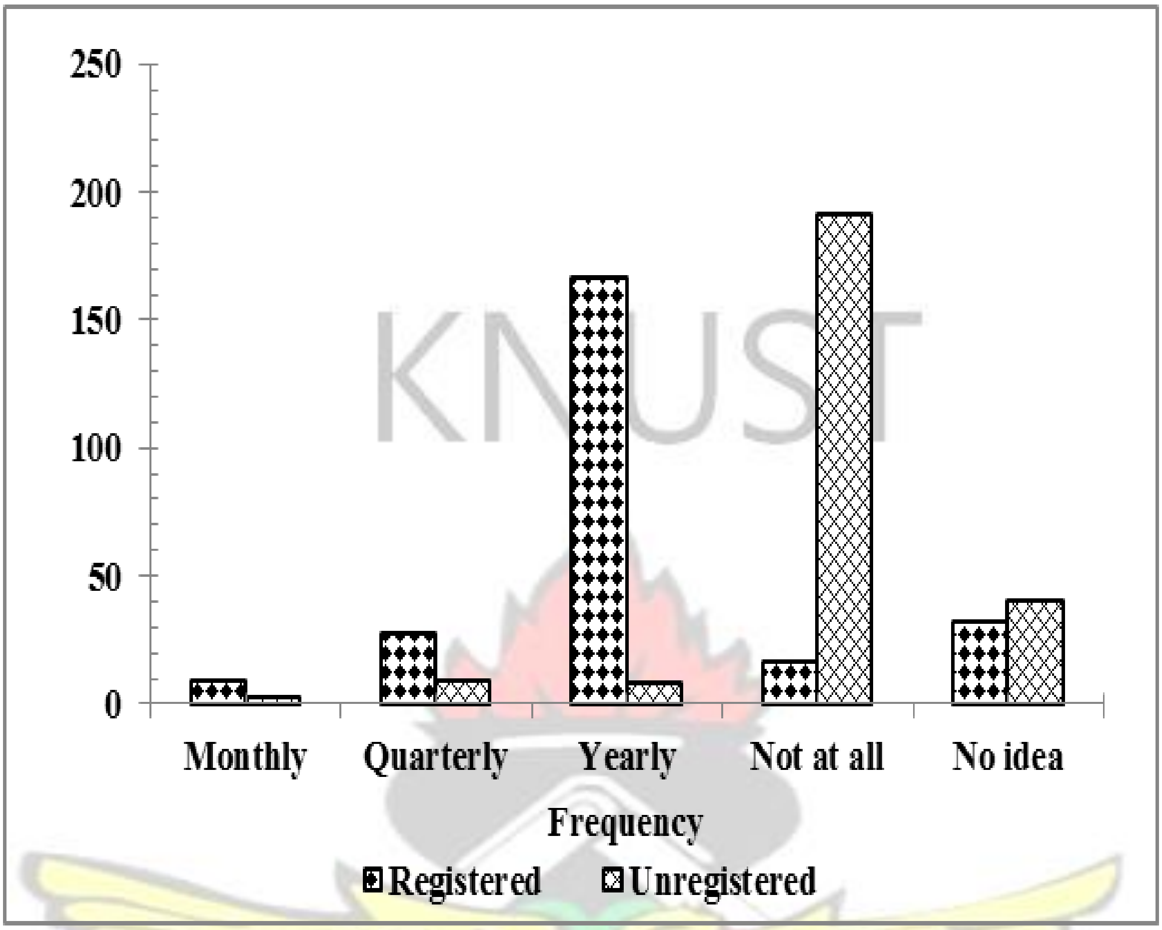

Figure 4.3: Field monitoring by regulatory authorities at ASM sites

4.4 ACCIDENT REPORTING

Additionally, respondents were asked to indicate whether all accidents are reported to the appropriate authorities. The results as shown in the Figure 4.4 suggest that, higher percentage of accidents occurring at Registered ASM sites were reported.

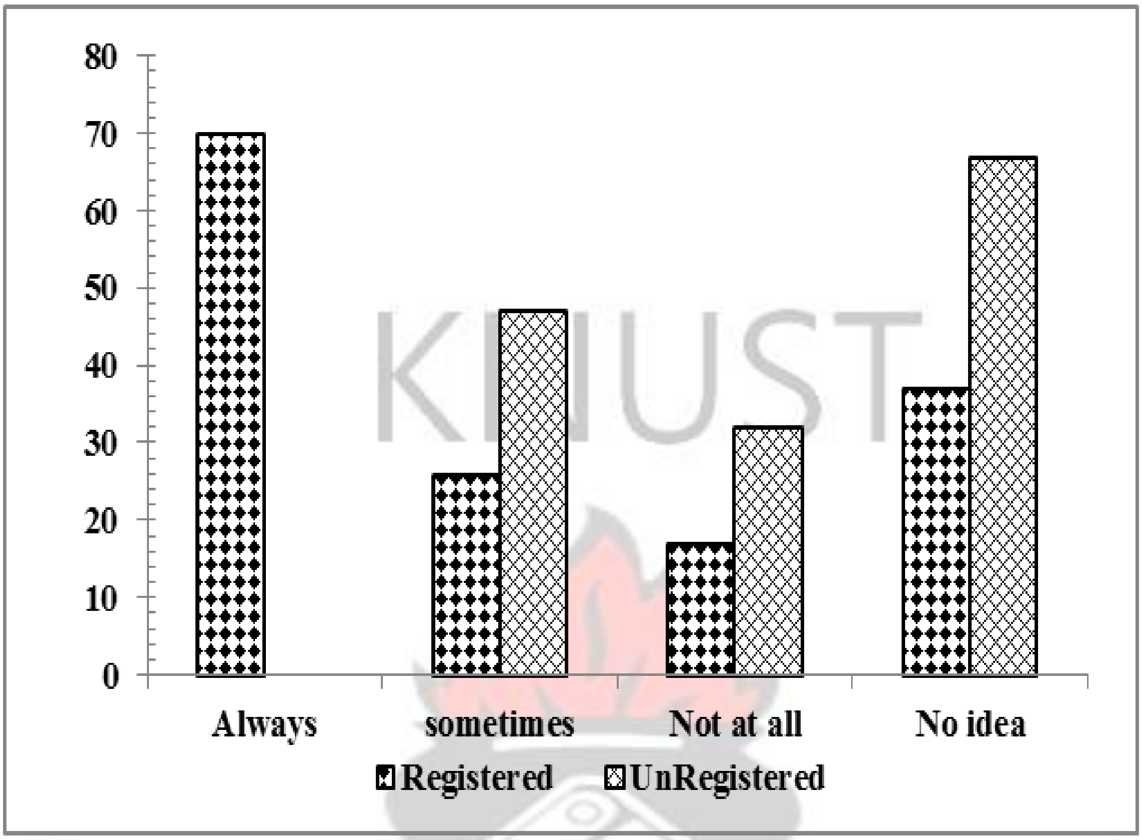

Figure 4.4: Comparison of accident reporting trends at registered and unregistered ASM sites.

On the contrary, accidents that occur at the unregistered sites were not reported at all. It was revealed during an interview session with some of the workers that their major reason for not reporting accidents was that their job will be under serious scrutiny by the enforcement agencies such as the police which can result in their being flushed from the site. They however, conceded that when the casualties were too many, they raise an 'alarm'. The ASM workers interviewed were not aware if any investigations conducted following an accident. From Figure 4.4, accidents occurring in registered sites are reported as compared with those occurring at unregistered sites. It is therefore difficult to collect actual accident / injury data in the ASM sector.

4.5 MOST COMMON CAUSES OF ACCIDENTS AT ASM SITES

Respondents were further asked to indicate the most common cause of accidents at

ASM sites as presented in Figure 4.5. From the Figure 4.5, one hundred and sixteen (116), representing 46% of the respondents believe that pit walls collapse resulting in mass of material falling under gravity is the major cause of ASM accidents. The next major cause is blasting related accidents which were supported by 24% of the respondents. Following closely as the next major cause is flooding with 20% and then suffocation resulting from confined space work at 8%.

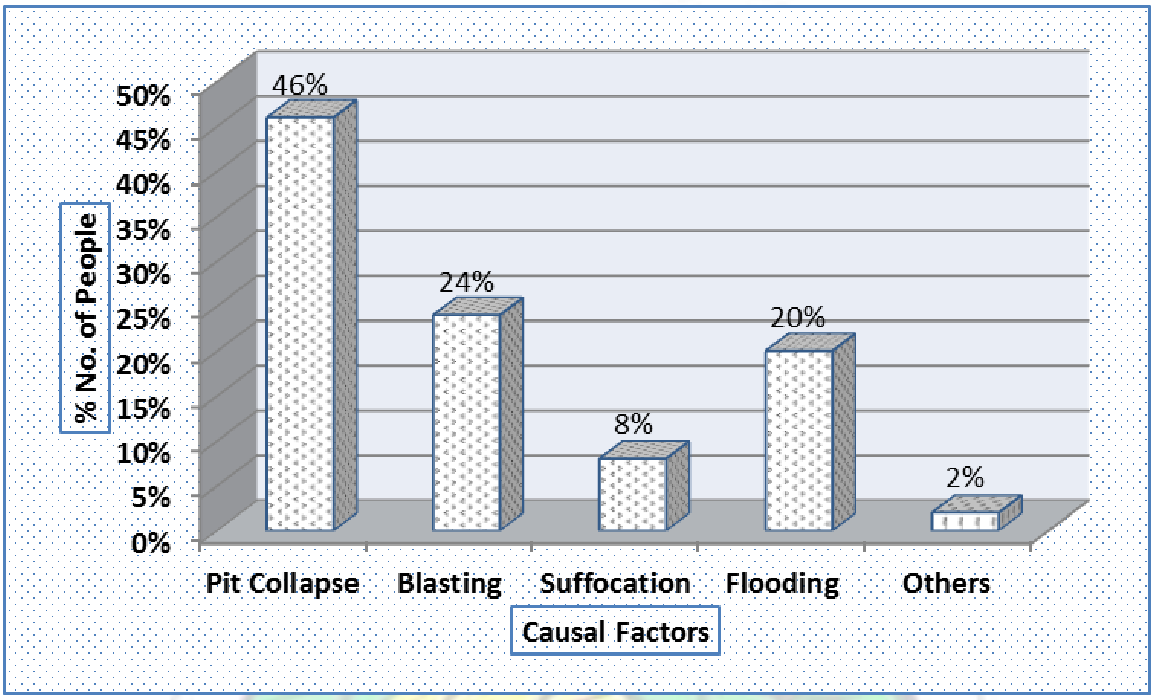

Figure 4.5 Most common causes of accidents at ASM sites

4.6 SILICA DUST MONITORING RESULTS AT ASM SITES

The results of the silica dust sampling are shown in Table 4.1. The results ranged from 0.033mg/m^3 to 0.083mg/m^3. The Occupational Exposure Limit (OEL) for silica dust over 12hrs is 0.034mg/m^3 according to the American Conference of Governmental Industrial Hygienists (ACGIH). All the results except the one from D-R3 were above the OEL.

Table 4.1 Silica dust monitoring results

		Results in mg/m^3	Results in mg/m^3
Sites	Sites codes	Actual (OE)	ACGIH (OEL)
Asankran Saa	AS-U1	0.048	0.034
A-R1	A-R1	0.066	0.034
Wassa- Dunkwa	WD-R2	0.081	0.034
Domenase	D-R3	0.033	0.034
Bremang	B-U2	0.054	0.034
Sikamenaso	S-U3	0.071	0.034
Nkaseim	N-R4	0.068	0.034
Akentensu	A-R5	0.074	0.034
Adengo	A-U4	0.062	0.034
Kenyasi No.2 Cemetery	K2-U5	0.083	0.034

Figure 4.6 also shows the relationship between the actual occupational exposures and the standard Occupational Exposure Limit (OEL) of the samples taken. All the sites had values above the OEL indicating that, the crushing of ore at these sites generate large quantities of silica dust. Therefore, if efforts are not made to reduce the dust exposure, the possibility of the miners being exposed to health effects of silica particularly silicosis, could be high.

Figure 4.7 depicts the massive dust exposure during the milling of the sand at Sikamenaso which explains the overexposure of the operators to the silica dust levels at that site.

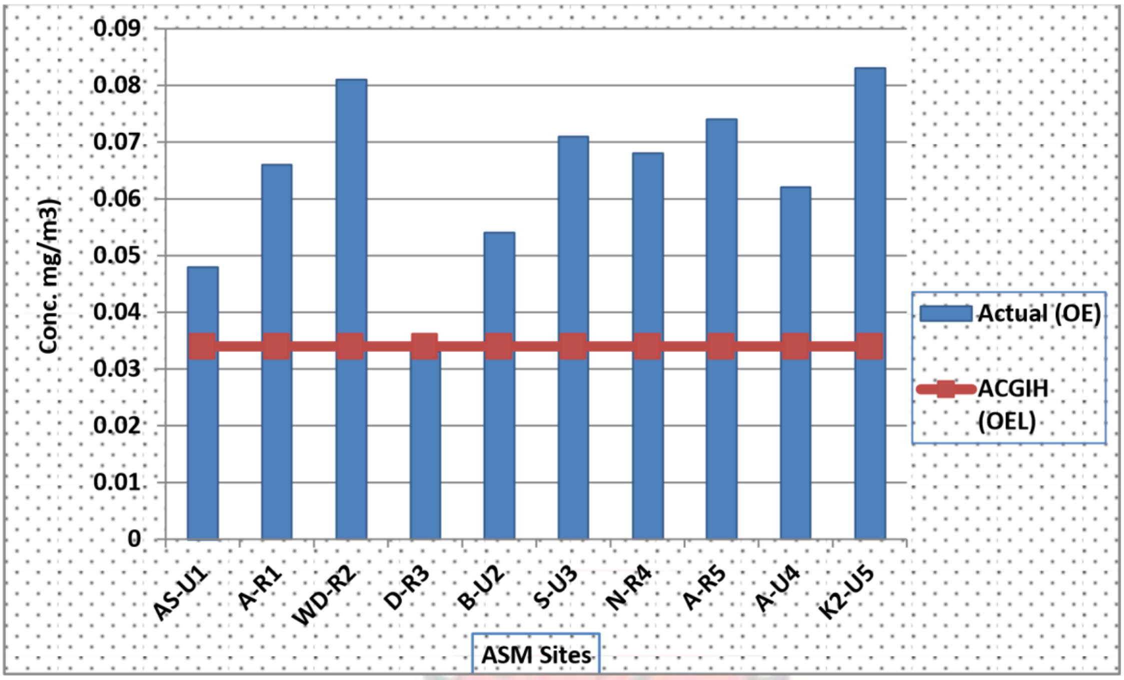

Figure 4.6 Dust monitoring results at ASM sites

Figure 4.7 Crushing at Sikamenaso in the Kenyasi area exposing dust. No use of respiratory protection devices was observed.

4.7 NOISE MONITORING RESULTS

Personal noise exposure levels were taken from the crushing plant operators at the study sites using a personal noise dosimeter. The results ranged from 87dB (A) to 112dB (A). According to the ACGIH, OEL for noise exposure is 85dB (A) for an 8 hours shift. Results are presented in Table 4.2.

Table 4.2 Noise monitoring results

Sites	Site codes	Actual (OE) / dB(A)	ACGIH (OEL)) / dB(A)
Asankran Saa	AS-U1	87	85
Agona	A-R1	105	85
Wassa- Dunkwa	WD-R2	91	85
Domenase	D-R3	99	85
Bremang	B-U2	95	85
Sikamenaso	S-U3	112	85
Nkaseim	N-R4	111	85
Akentensu	A-R5	103	85
Adengo	A-U4	96	85
Kenyasi No. 2 Cemetery	K2-U5	107	85

All noise levels measured were above the OEL. The crushing process is noisy but the crusher operators' work stations are not isolated from the source of the noise as compared with the advanced crushers used by the commercial mining companies. The poor maintenance condition of the crushing plant could also contribute to the excessive noise generated.

Figure 4.8 also shows the relationship between the actual occupational exposures and the standard OEL. From Figure 4.8, all those operators working in the crushing zones are at risk of noise induced hearing loss unless preventive measures are taken to minimize the level of their exposure. Sound pressure falls inversely proportional to distance from the source of noise but the operators work stations are in close proximity to the source of the noise generated during crushing leading to the high levels of noise by the crushing plant operators.

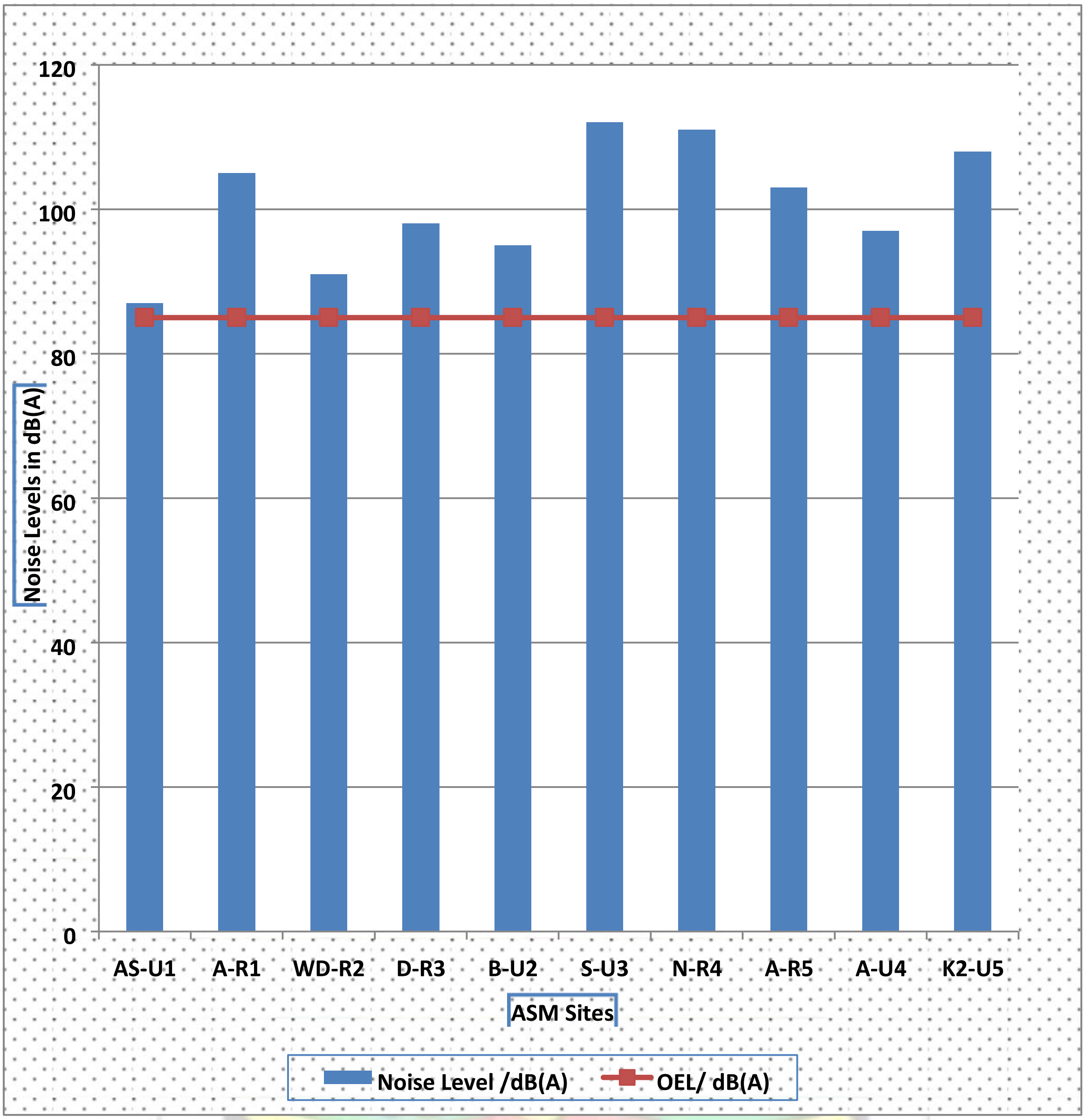

Figure 4.8 Noise monitoring results.

4.8 DEGRADED LAND

Table 4.3 shows the extent of land degradation caused by artisanal and small-scale miners.

Table 4.3 Degraded Land monitoring results

Sites	Sites Codes	Land Allocation for the ASM sites *1000 m^2	Disturbed Area of Land *1000 m^2	% of Land Area Disturbed
Asankran Saa	AS-U1	120	105	87.5
Agona	A-R1	60	45	75.0

Wassa- Dunkwa	WD-R2	410	325	79.3
Domenase	D-R3	92	63	68.5
Bremang	B-U2	112	90	80.4
Sikamenaso	S-U3	415	350	84.3
Nkaseim	N-R4	165	140	84.8
Akentensu	A-R5	96	79.8	83.1
Adengo	A-U4	92	58.8	63.9
Kenyasi No.2 Cemetery	K2-U5	65.5	43.2	66.0
Total Area		**1627.5**	**1299.8**	**80**

About 1.3 million m^2 of land representing about 80% of land used for ASM activities had been destroyed through top soil removal with heavy machines, covering of land with rocks and other mining waste materials, creation of pits which eventually become fatal zones.

4.9 ACCIDENT RATES

4.9.1 Total Reportable Injury Frequency Rate (TRIFR) & Fatal Incident Frequency Rate (FIFR) Calculations.

The number of all the injuries sustained by the ASM workers other than minor first aid injuries were recorded as Total Reportable Injuries as indicated in column five of Table 4.4. The number of fatal cases was also recorded as shown column six of Table 4.4. This data was provided by the ASM operators in the study areas for a one year period spanning April 2012 – March 2013. The man hours worked was calculated using the formula:

Total Man-hours *= Number of workers x Number of months worked in a year x Number of days worked in a month x No. of hours worked in a day* (OSHA, 2009).

Table 4.4 Accident rates (TRIFR & Fatality Rate)

Sites	Sites Codes	Total No. of workers	Total Manhours / Year (Approximate)	No. of Total Reportable Injuries	No. of Fatalities	FIFR	TRIFR
Asankran Saa	AS-U1	3800	9500000	35	3	**0.06**	0.74
Agona	A-R1	5400	13500000	-*	2	0.03	*
Wassa- Dunkwa	WD-R2	7300	18250000	40	3	0.03	0.46
Domenase	D-R3	3300	8250000	-*	1	0.02	*
Bremang	B-U2	1200	3000000	-*	4	**0.27**	*
Sikamenaso	S-U3	5200	13000000	65	7	**0.11**	1.00
Nkaseim	N-R4	7000	17500000	-*	5	**0.06**	*
Akentensu	A-R5	6100	15250000	45	1	0.01	0.59
Adengo	A-U4	1700	4250000	48	0	0.00	2.26
Kenyasi No.2 Cemetery	K2-U5	400	1000000	-*	1	**0.20**	*

-* information not available at time of survey.

The Fatal Incident Frequency Rate (FIFR) in column seven of Table 4.4 was calculated as follows.

$$\text{Fatal Incident Frequency Rate (FIFR)} = \frac{\text{Number of Fatal Cases}}{\text{Total Man-hours}} \times 200,000$$

The Total Reportable Injuries Frequency Rate (TRIFR) in column eight of Table 4.4 was calculated as follows.

$$\text{Total Reportable Injuries Frequency Rate (TRIFR)} = \frac{\text{Number of Reportable Injuries}}{\text{Total Man-hours}} \times 200,000$$

The standard base rate for the calculations was based on a rate of 200,000 labour hours which equates to 100 employees, who work 40 hours per week, and 50 weeks per year (OSHA, 2009). Both the injury and the fatality rates were relatively higher at the unregistered sites. Only Adengo, one of the unregistered sites recorded a fatality rate of zero but with high reportable injury. According to Bird (1969), for every reported major injury (resulting in fatality, disability, lost time or medical treatment) there were 9.8 reported minor injuries (requiring first-aid), 30.2 property damage accidents, and 600 incidents. This suggests that, there is high probability of fatality occurring if standard working procedures are not implemented at the Adengo site.

4.10 **RISK ANALYSES**

4.10.1 Hazards and Risks Associated with ASM

The likelihood table in Table 4.5 was used to determine the chance that a hazard identified to be associated with ASM activity could result in an accident or incident. The determination is based on historical evidence or experience using a scale of rating of 1-5 to indicate increasing probability of an event to occur.

Table 4.5: The Likelihood Table

Level	Description	Criteria (read as either/or)
5	Certain	The event is expected to occur in the most circumstances
		Risk has more than a 75% chance of occurring
		The event will occur within the next six months
4	Likely	The event will probably occur in most circumstances
		Risk has more than a 50-74% chance of occurring
		The event occur within 18 months
3	Possible	The event could occur at some time
		Risk has 25-49% chance of occurring
2	Unlikely	The event is unlikely to occur
		Risk has less than 25% chance of occurring
		Will occur within 48 months
1	Rare	The event may only occur in exceptional circumstances
		Not likely to occur within the next five years

Source: (Bass, 2010)

The consequence table, Table 4.6 was used to determine the consequence of an accident occurrence. The determination was also based on a scale of measurement from 1-5 to indicate increasing severity of the consequence of an accident.

Table 4.6: Consequence table: Criteria indicating impact scenarios and ratings

Rating	Estimated Cost	Health & Safety	Environmental	Community	Operational	Security	Legal Compliance
1	Insignificant > $1,000	First Aid Injury Nuisance value	No or very low environmental impact Impact confined to small area	Isolated complaint No media enquiry	Loss equivalent to 1 hour of production interruption Routine wear and tear of screen panels at crusher requires change out.	Infractions: Violations of internal policies and procedures No personal injury of property damage	Minor technical/legal compliance issue unlikely to attract a regulatory response
2	Minor > $10,000	Medical Treatment Injury Restricted Work Injury	Low environmental impact Rapid cleanup by site staff and/or contractors Impact contained to area currently impacted by operations	Small numbers of sporadic complaints Local media enquiries	Loss equivalent to 6 hours of production interruption Metal tooth on loader bucket comes loose while feeding crusher. Crusher plugged and tooth has to be cut out of crusher.	Minor Criminal Offenses Example: Trespassing, Theft under $5000.00, Minor Property Damage, etc.	Technical/legal compliance issue which may attract a low level administrative response from regulator Incident requires reporting in routine reports (e.g. monthly)
3	Moderate > $100,000	Single Lost Time Injury	Moderate impact Cleanup by site staff and/or contractors Impact confined within lease boundary	Serious rate of complaints, repeated complaints from the same area Increased local media interest	Loss equivalent to 12 hours of production interruption The pressure oxidation vessel develops a small leak in the brick liner.	Appreciable property damage Theft over $10,000.00 value Low intensity civil unrest	Breach of regulation with possible penalties Continuing occurrences of minor breaches Incident requires immediate (within 48 hours) notification.
4	Major > $1,000,000	Multiple Lost Time Injuries Admission to intensive care unit or equivalent Serious, chronic, long term effects	Major environmental impact Considerable cleanup effort required using site and external resources. Impact may extend beyond the lease boundary.	Increasing rate of complaints, repeated complaints from the same area Increased local/ national media interest	Loss equivalent to 3-7 days of production interruption Equipment for gas cleaning at the roaster facility fails and requires replacement. Ground fall at the open pit closes of access road and buries equipment.	Significant property damage resulting in shut downs Significant Criminal offenses committed against persons. High intensity civil unrest High level fraud	Major breach of regulation resulting in investigation by regulator Prosecution, penalties or other action likely

5	Catastrophic >$10,000,000	Fatality(s) or permanent disability	Severe impact Local species destruction and likely long recovery period Extensive cleanup involving external resources Impact on a regional scale	High level of concern or interest from local community National and/or international media interest	Loss equivalent to more than a week of production interruption Pressure oxidation vessel fails and depressurizes Ground fall at an underground heading causes loss of entire heading.	Major criminal offenses Multiple fatalities Forced evacuation of all personnel	Serious breach of regulation resulting in investigation by regulator Operation suspended, licenses revoked.

Source; Newmont Ghana Limited (2012)

Table 4.7 is the risk matrix upon which the risk assessment for ASM activities in table 4.8 was based. The estimated likelihood in column one of Table 4.7 of a hazard to result in an accident is multiplied by the estimated consequence in row two of Table 4.7. The product of the multiplication of the likelihood and the consequence gives the risk rating for the particular hazard.

Table 4.7: 5X5 Risk matrix showing levels of significance rating

RISK INDEX MATRIX	**Consequence Rating**				
Likelihood Rating	**1 Insignificant**	**2 Minor**	**3 Moderate**	**4 Major**	**5 Catastrophic**
5 Certain	Low 5	Medium 10	High 15	Extreme 20	Extreme 25
4 Likely	Low 4	Medium 8	High 12	High 16	Extreme 20
3 Possible	Low 3	Medium 6	Medium 9	High 12	High 15
2 Unlikely	Low 2	Low 4	Medium 6	Medium 8	Medium 10
1 Rare	Low 1	Low 2	Low 3	Low 4	Low 5
Index Significance Priority	LOW (1-5)	MEDIUM (6-10)	HIGH (11-17)	EXTREME (18-25)	

Source: (Anon, 2007)

The risk assessment for ASM activities is shown in Table 4.8. Table 4.8 is in seven parts thus Table 4.8 (1-7). The hazard(s) associated with the steps in processes involved in ASM were identified and noted as shown in column 2 of Table 4.8.

Table 4.8: Risk Assessment of Artisanal and Small scale Mining Operation

Type of Assessment	Reference Number	Date	Activity area		Page number
ISSUE BASED	…………….	………..	Asankrangwa and Kenyasi		……………

Hazard No. (H1)	**1**	Digging out surface excavations (Activity/plant/Task)

Cause/Step/Task	Hazard	Initial L	Initial C	Initial R	Recommended Measures/Comments	Residual L	Residual C	Residual R	Responsible Person
• Manual handling of hand tools and equipment	1. Bodily pains and cuts	5	4	20	1. Install conveyor systems to aid movement of loads to and from ground. 2. Reduce weight of loads and get help. 3. Rotate workers on regular basis. 4. PPE – gloves,	3	3	9	Facility Owner
• Handling of heavy loads	2. Deafness and hearing loss from air compressors (…up to 105dBA)	4	4	16	1. Purchase lowest decibel compressors. 2. Put machines on PM schedules. 3. PPE - Suitable hearing protectors.	3	3	9	Equipment owner
	3. Loose material and load falling in to excavations.	4	5	20	1. Maintain a minimum of two feet from the edge of the excavation to the spoil.	3	4	12	Facility Owner
• Improper House Keeping	4. Fall from height during access and egress into excavations	4	5	20	1. Provide ladder of suitable length. 2. Train users to maintain 3point of contact during access and egress.	3	3	9	" "
	5. Water inrush	3	3	9	1. Check that there are no underground water piping systems or water source. 2. Install dewatering systems/equipment	2	2	4	" "
	6. Ground collapse due to ground instability.	4	5	20	1. Use benches or berms or batters. 2. Installation of ground support systems (i.e. shoring)	3	4	12	" "
	7. Vibration - Hand Arm Vibration Syndrome (HAVS) and Vibration White Finger (VWF), Repeatitive Strain Injury (RSI) over time	4	3	12	1. Purchase lowest air compressors. 2. Select appropriate equipment, monitor and carefully regulate exposure times. 3. Correct maintenance for A/V systems, chain and bar. 4. PPE - gloves.	3	2	6	" "

Type of Assessment	Reference Number	Date			Activity area				Page number
ISSUE BASED	…………….	………..			Asankrangwa and Kenyasi				……………
Hazard No. (H2) **2**	Use of Explosives (Activity/plant/Task)								
Cause/Step/Task	Hazard	Initial			Recommended Measures/Comments	Residual			Responsible Person
		L	C	RR		L	C	RR	
• Improper storage of explosives and detonators • Improper handling of explosives	**1.** Premature initiation during transport	4	5	20	1. Provide standard storage magazines with safety labels. 2. Do not store or leave any combustible materials within 8 m of magazines. Keep grass close to magazines cut very short. 3. Never store detonators in the same magazine as explosives. 4. Always use old stock first. 13. Do not overload magazines. Stack cases so they cannot fall.	3	4	12	Facility Owner / Mining support Engineers
during loading and stemming of blast holes • Lack of security and use of	2. Potential to cause premature initiation, fly rock and misfires, Loss of downtime	4	5	20	1. Avoid impact on detonators. 2. Do not attempt to pry detonators open to investigate the contents. 3. Do not attempt to pull the leg wires out of the detonators. 4. Do not carry detonators in your pockets. 5. Institute system to ensure good communication. 6. Secure attachment system and use correct stemming method.	3	4	12	“ “

unqualified persons	3. Personal injury	4	4	16	1. Magazines must be locked at all times and access to keys controlled. 2. Store only authorized explosives in explosives magazines.	3	3	9	" "
I n a d e q u a t e ti e	4. Misfire and injury	3	4	12	1. Employ simple tie up system mechanism 2. Use competent persons only	2	3	6	" "
	5. Fly rock, fumes, dust, fireball - to injury to persons, equipment damage etc.	4	5	20	1. Establish adequate communication system. 2. Distance block offs, firing by competent persons 3. Adequate post firing inspection system.	3	3	9	" "
	6. Premature initiation	3	5	15	1. Time interval – post firing inspections. 2. Accurate marking of inaccessible misfires and correct procedure to deal with during excavation. 3. Personnel competency.	2	4	8	" "
	7. Inadequate coordination and communication	3	5	15	1. Establish adequate communication system.	2	4	8	" "
	8. Noise and vibration which can lead to structural failures.	4	4	16	1. Distance block offs, firing by competent persons 2. Authorized entry only at blasting zones during blast. 3. PPEs	3	3	9	" "

	u p	9. Personal injuries	4	5	20	1. Distance block offs, firing by competent persons 2. No unauthorized entry at blasting zones during blast.	3	4	12	" "

Type of Assessment	Reference Number	Date	Activity area		Page number
ISSUE BASED	…………….	………..	Asankrangwa and Kenyasi		……………

Hazard No. (H3)	**3**	Tunneling or constructing adits (Activity/plant/Task)

Cause/Step/Task	Hazard	Initial L	Initial C	Initial RR	Recommended Measures/Comments	Residual L	Residual C	Residual RR	Responsible Person
• Digging of ground • Furnishing tunnel with vital services • Material transport	1. Ground failure	3	5	15	Ground support, e.g. tunneling shields, mesh, rock bolts and shotcrete	2	4	8	Facility Owner / Mining support Engineers.
	2. Ground competency	3	4	12	1. Regular monitoring by Geological and geotechnical information.	2	3	6	" "
	3. Limited or confined spaces	3	3	9	1. Mechanical ventilation to control airborne contaminants and air temperature/humidity. 2. Dust extraction 3. Provision of breathing equipment when a hazardous atmosphere is present and cannot be effectively ventilated by external means.	2	2	4	" "
	4. Air contamination or oxygen depletion	3	4	12	1. Mechanical ventilation to control airborne contaminants and air temperature/humidity. 2. Dust extraction. 3. Provision of breathing equipment when a hazardous atmosphere is present and cannot be effectively ventilated by external means.	2	3	6	" "
	5. Overhead seepage, causing flooding at site	3	3	9	1. Pumps or dewatering systems to remove ground water, and regular geotechnical survey/monitoring.	2	2	4	" "
	6. Falls of people/ objects	3	3	9	1. Provide safe means of access and egress. 2. Use cable bolting and or wire mesh as reinforcement.	2	3	6	" "
	7. Contaminated groundwater from oil spills and chemical use	2	5	10	1. Keep all earthworks tools in good mechanical condition. 2. Use absorbent pads/booms and pump out all contaminated water into a containment for treatment before disposal.	3	3	9	" "
	8. Heat and humidity	3	3	9	1. Install ventilation equipment and improve lighting	3	2	6	" "
	9. Temporary electrical or lighting supplies and poor ventilation	4	3	12	1. Keep electrical plant under planned maintenance schedule. 2. Regular inspection.	3	2	6	" "
	10. Hydraulics Exposure to Noise, vibration and dust.	2	4	8	1. Low decibel compressors. 2. PM schedule. 3. Training. 4. PPE –Gloves, ear plugs etc.	1	3	3	" "
	11. Large scale materials and equipment handling	3	4	12	1. Develop a pulley system to reduce manual handling. 2. Manual handling training.	2	3	6	" "
	12. Ground gas and water inrush	3	3	9	1. Pumps or dewatering systems to remove ground water. 2. Gas detection systems	2	3	6	" "

Type of Assessment	Reference Number	Date	Activity area		Page number
ISSUE BASED	…………….	………..	Asankrangwa and Kenyasi		……………

Hazard No. (H4)	**4**	Sinking of Shaft (Activity/plant/Task)

Cause/Step/Task	Hazard	Initial L	Initial C	Initial RR	Recommended Measures/Comments	Residual L	Residual C	Residual RR	Responsible Person
Limited Shaft dimensions; limiting work space.	1. Confined space workplace injuries	4	4	16	1. Mechanical ventilation to control airborne contaminants and air temperature/humidity. 2. Dust extraction. 3. Provision of breathing equipment when a hazardous atmosphere is present and cannot be effectively ventilated by external means.	3	3	9	Facility Owner / Mining support Engineers
	2. The potential for ground instability whilst lifting and removing spoil	3	4	12	1. Stabilizing the ground at the head of the shaft and removal of spoil. 2. Continuously lining or supporting the shaft	2	2	4	" "
	3. Defective hoisting equipment (e.g. winch, ropes and hooks)	4	5	20	1. Providing and maintaining appropriate hoisting equipment	3	4	12	" "
	4. Inadequate communication systems during underground operations.	3	3	9	1. Establish sound communication system. 2. Training for mine workers	2	3	6	" "
	5. Improper mining technique leading to overhanging or undercutting and subsequent failures	4	5	20	1. Adapt safe mining principles such as 1. Benching and battering of pits. 2. Positive ground support for example shoring. 3. Installation of shields. 4. Monitoring the condition & stability of pit walls, berms and stockpiles	3	4	12	Facility Owner
	6. Falls and falling objects, including fine material and water from the shaft wall	4	4	16	1. Maintain a minimum of two feet from the edge of the shaft to the spoil. 2. Provide wall support.	3	3	9	Facility Owner / Mining support Engineers

Type of Assessment	Reference Number	Date	Activity area		Page number
ISSUE BASED	…………….	………..	Asankrangwa and Kenyasi		……………
Hazard No. (H5)	**5**	Working underground (Activity/plant/Task)			

Cause/Step/Task	Hazard	Initial			Recommended Measures/Comments	Residual			Responsible Person
		L	C	RR		L	C	RR	
	1. Poor geological and geotechnical conditions	2	5	10	1. Competent person to check and monitor regularly for these vital signs such as: Seepage along the slipping plane, Water seeping into the excavation and Tension cracks on the surface and bulging side walls etc.	2	4	8	Facility Owner / Mining support Engineers
	2. Inadequate / lack of installed ground support leading to failures and serious and fatal injuries.	4	4	16	1. Ground support installations by competent persons. 2. Regular checks. 3. Geological and geotechnical conditions monitoring.	3	4	12	" "
	Collapse or slump of wall	3	5	15	1. Benching and battering of pits. 2. Positive ground support for example shoring. 3. Installation of shields. 4. Monitoring the condition & stability of pit walls, berms and stockpiles	2	5	10	" "
• Excavation of ore	Materials falling off due to undercutting	4	4	16	1. Maintain a minimum of two feet from the edge of the excavation to the spoil. 2. Get a spotter and ensure good communication and housekeeping. 3. Use of PPEs.	2	3	6	" "
	Instability of the excavation and adjoining structure	3	5	15	1. Geological and geotechnical conditions monitoring (e.g. Slope angle reduction and installing reinforcement	2	4	8	" "
• Transportation of materials and equipment down and up the shaft	System Failures etc????	4	4	16	1. Establish safe means of access and egress of personnel and materials include installation of pulley systems.	2	3	6	" "
	Access to subsidence zones	3	4	12	1. Obtain adequate geological information.	2	3	6	" "

Type of Assessment	Reference Number	Date	Activity area		Page number

ISSUE BASED		…………….	………..	Asankrangwa and Kenyasi					……………
Hazard No. (H6)	**6**	Working in poorly unconsolidated terrains (Activity/plant/Task)							

Cause/Step/Task	Hazard	Initial L	Initial C	Initial RR	Recommended Measures/Comments	Residual L	Residual C	Residual RR	Responsible Person
Uncoordinated excavations and or material removal from working environment	Dam, diversion or storage facility collapse	4	5	20	Monitor dam levels and provide spill ways as necessary. Monitor the strength of the retaining walls.	2	4	8	Facility Owner / Mining support Engineers
	Inrush into/flood intrusion of mine area (Directly or indirectly)	3	5	15	1. Check that there are no underground water piping systems or water source. 2. Install dewatering systems/equipment	2	4	8	" "
	Failure of pumping system e.g. outlet blockage	3	3	9	PM schedule	2	2	4	" "
	Unusual rain event	3	4	12	Programs to halt work during natural hazardous event	2	3	6	Facility Owner /
	Material fall / failure	3	5	15	1. Geological and geotechnical conditions monitoring (e.g.) Slope angle reduction and installing reinforcement 2. Training of site personnel on dangers of working with loose materials.	3	5	15	Facility Owner /

Type of Assessment		Reference Number	Date	Activity area		Page number
ISSUE BASED		…………….	………..	Asankrangwa and Kenyasi		……………
Hazard No. (H7)	**7**	Treatment and Processing (Activity/plant/Task)				

Cause/Step/Task	Hazard	Initial L	Initial C	Initial RR	Recommended Measures/Comments	Residual L	Residual C	Residual RR	Responsible Person
• Inappropriate access to operating	Personal injuries	3	4	12	1. Machine guarding. 2. Formal training of operators and fitters. 3. Safety signs (no loose clothing on rotating parts)	2	3	6	Facility Owner / Mining support Engineers

machinery	Mechanical failure (including critical systems i.e. pressurized cylinders) etc.	3	4	12	1. PM schedule for all critical systems. 2. ‘Makeshift’ tools/equipment to be in good working condition.	2	3	6	“ “
• Crushing of ore	Unwanted pressure releases such as intensification, equipment failure	4	4	16	1. Safety pins on all couplings. 2. Whip checks installed 3. Regular monitoring. 4. Training. 5. PM schedule	2	3	6	“ “
• Milling of ore	all forms of mechanical and physical hazards	4	4	16	1. Improve maintenance 2. Isolate crushing plant from densely populated areas 3. PPEs – nose and eye protection	3	3	9	Facility Owner
	Contact with mercury during handling (e.g. Skin contact, Inhalation of vapours, Ingestions etc.).	5	4	20	1. Avoid skin contact – use PPEs (gloves, overall and respiratory protection)	4	3	12	Facility Owner / Mining support Engineers
	Chemical contamination leading to loss of; Groundwater quality, Flora and fauna.	4	4	16	1. Enforce Mercury regulation. 2. Conduct periodic monitoring of streams and rivers in the vicinity of mine area.	3	3	9	Minerals Commission / EPA

L = Likelihood, C = Consequence, R= Risk Rating

The likelihood (L) of the hazard to result Table 4.8 at an accident or incident was rated in column three. Similarly, the consequence (C) of the event was also rated in column four. The initial Risk Rating (RR) which was arrived at after marching the Likelihood and the Consequence using the risk matrix table in Table 4.7 was determined in column 5. Control measures were put in place in column six using the hierarchy of control; elimination > substitution > isolation > administration > Personal Protective Equipment(s) (PPEs) to mitigate the risks of incidents occurring.

Also in Table 4.8, it can be inferred that the initial risk rating was obtained without taking into consideration any prior controls. The residual risk rating was however obtained after putting in place controls to mitigate the hazards. All the residual risk rating were lower than the initial risks which support the fact that if control measures are put in place at ASM sites, there would be a reduction in the risk of accident occurrence.

4.10.2 Risk prioritization

The average overall risk ratings of the seven hazards categories were calculated to determine which of the hazards were still high after the inception of recommended controls. This was done to ensure the high risk hazard categories were managed in order of priority to prevent accidents. The priority table in Table 4.9 was used as a guide in prioritizing the risks to provide insights to the ASM operators on where resources should be directed to manage or mitigate the realization of high probability or high consequence risk events.

Table 4.9: Risk priority table

Risk Level	Priority	Actions to manage risk

Extreme (18-25)	1	The risk is assigned to senior person in the project who is held accountable. Detailed research is required to determine if activity should be stopped pending further investigations.
High (11-17)	2	Higher level responsibility required. Corrective action plan developed and followed.
Medium (6-10)	3	Conditionally acceptable risk. Responsibility assigned, monitoring and review assigned.
Low (1-5)	4	Managed by routine procedures; accept risks

Source: (Author, 2013)

A summary of the initial and residual ranking of hazards are presented in Figure 4.9. All seven hazard categories (H1 – H7), during initial Risk Assessment using a 5X5 risk matrix presented **extreme** to **high** risk significance. After inception of recommended controls, all the seven hazard categories were reduced to **medium** to **low** risk significance as indicated by the residual risk ranking data. The risk ranking prioritization was determined to be in the order of: Use of explosives (H2) > Surface excavations (H1) > Shaft sinking (H4) > Treatment and processing (H7) > Working underground (H5) > Working in poorly consolidated terrains (H6) > Making tunnels/adits (H3).

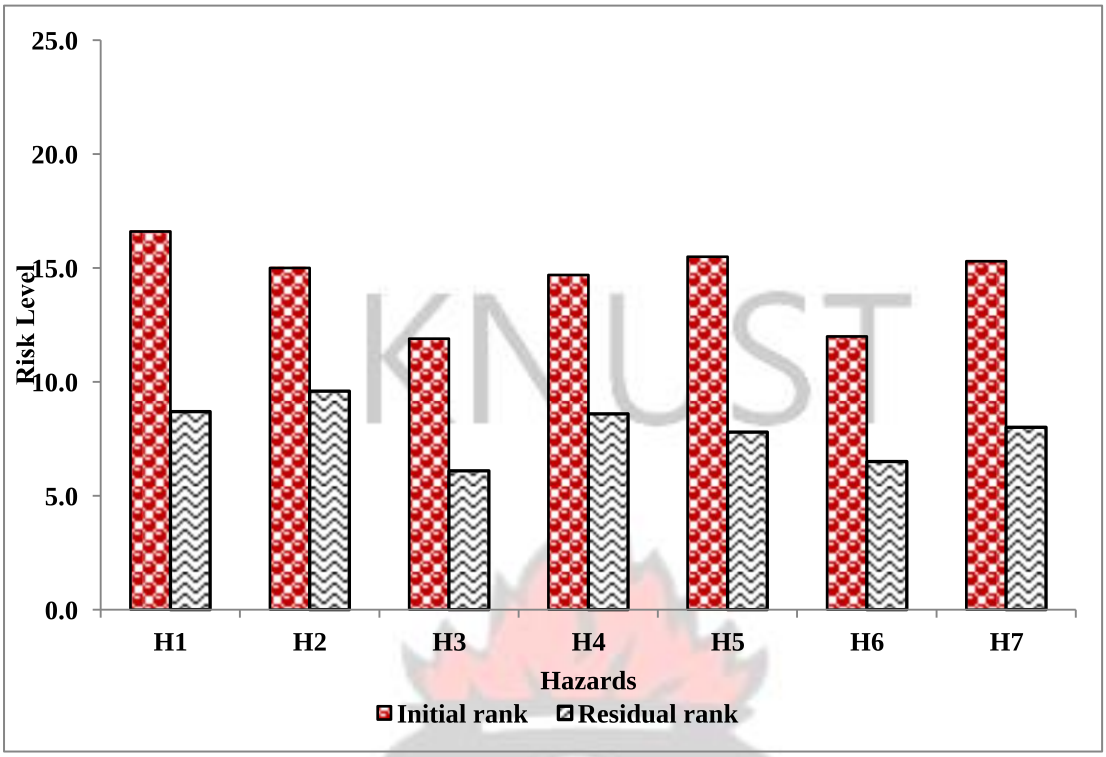

Figure 4.9 Summary of initial and residual risk ranking of hazards deduced from risk assessments.

<u>Key</u>

H1	Digging out surface excavations (Activity/plant/Task)
H2	Use of Explosives (Activity/plant/Task)
H3	Tunneling or constructing adits (Activity/plant/Task)
H4	Sinking of Shaft (Activity/plant/Task)
H5	Working underground (Activity/plant/Task)
H6	Working in poorly consolidated terrains (Activity/plant/Task)
H7	Treatment and Processing (Activity/plant/Task)

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSION

From the research, ASM workers practice unsafe acts and conditions and expose themselves to hazards and risks in their operations because they are ignorant about safety. This explains why majority of the ASM workers do not use Personal Protective Equipment (PPE) to safeguard themselves even as a last resort in managing the hazards they are exposed to.

The research also revealed that regulatory authorities visit the registered ASM sites to check conformance to health and safety standards annually but not the unregistered sites. Due to this monitoring regime by the regulatory authorities, the registered sites are compelled to follow some safety practices and rules. This helps in reducing accidents as compared with unregistered sites where due to their clandestine attitude are always amenable to sustaining accidents.

Most accidents that occur at registered ASM sites get reported. On the contrary, accidents that occur at the unregistered sites are not reported at all. It was revealed during an interview session with some ASM workers that the unregistered sites do not report accidents for fear of being flushed from their sites by the security agencies.

The main causes of ASM accidents were identified and placed under the following hazard types; working underground, use of explosives, surface excavations shaft sinking, treatment and processing, making tunnels/adits and working in poorly consolidated terrains. Initial risk assessment using the 5X5 risk matrix placed all seven main hazard types in the **high** to **extreme** risk significance range of risk ratings between (11-17) to (18-25) respectively. All these hazard types were reduced to **medium** to **low** risk significance range of (6-10) and (1-5) respectively after putting in place the necessary control measures. Prioritization was in the order: Use of Explosives > Surface excavations > Shaft Sinking > Treatment and Processing > Working underground > Working in Poorly Consolidated Terrains > Making Tunnels/Adits. Noise and silica dust exposure at the crushing areas were determined to be above their allowable limit. The land use survey also revealed about 80% of the land allotted for the ASM operations have been disturbed. Therefore action plans must be developed to ensure all lands /concessions given out to small-scale miners are utilized in the best environmental friendly manner to reduce the extent of degradation.

5.2 RECOMMENDATIONS

Based on the results of the risk assessment, efforts should be directed at ensuring all the safety requirements regarding the use of explosives at the ASM sites are fully enforced to prevent accidents and fatalities followed by surface excavations, working in shafts, treatment and processing, working underground, working in poorly consolidated terrains and making tunnels in the order.

It is also recommended that

1) risk assessments must be a requirement for starting ASM business in the country. And all ASM workers must be inducted to enable them identify hazards and manage them effectively to control or prevent possible accidents.

2) Government should encourage and assist the illegal miners 'galamsey operators' to acquire permits so that their activities can be monitored by the regulatory authorities.

3) Accident reporting and investigations procedures should be established and records kept. This will assist in determining the root cause of all ASM accidents and also

allow authorities to direct resources to curb incidents and accidents with a high loss potential.

4) Regular audits of performances and reviews should be initiated to check conformance to set standards.

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APPENDIX 1

Project Topic: Evaluation & Prevention of some cause of ASM accidents within Asankrangwa and Kenyasi Areas.

Visit to Minerals Commission – Asankrangwa

1. I know you play a lead role in Artisanal Small-Scale Mining? What specifically do you do as far as ASM operations are concerned?

…………………………………………………………………………………………

2. How is the registration of ASMs done? Are there any forms to fill? Can I see a copy? What is the cost involved?........................

3. What consideration is given before registration is done?

……………………………………………………………………………………………

4. How many registered ASMs do we have in this Area? How many of the ASMs are also operating illegally in the area?………………

……………………………………………………………………………………………

5. What methods of mining are practiced in this area?

……………………………………………………………………………………………

6. What are the likely health and safety impacts associated with the methods used.……………………………………………………………………………………

7. Do the ASM operators submit reports on regular basis to you? What kind of reports?

……………………………………………………………………………………………

8. How often do you receive reports of environmental damage by the ASM operations?

……………………………………………………………………………………………

9. How often do you receive reports of health and safety by the ASM operations?

……………………………………………………………………………………………

10. How do you receive these reports?...

11. Do you investigate these reports? What has been the most occurring immediate causes?

…………………………………………………………………………………………

12. What are the frequently occurring basic or underlying causes?

…………………………………………………………………………………………

13. Do you provide ASM operatives on health and safety measures? What are some of the safety requirements to be complied with at the ASM sites? What punitive measures exist for breach of health and safety requirements? Has any ASM suffer such punitive measures yet?

…………………………………………………………………………………………

14. What are the accident rates in this area?

…………………………………………………………………………………………

15. What has been the most occurring consequence of the reported accidents?

a) Fatalities………..…………….. Disabling Injuries…..……………Minor Injuries……..………P.Dam……….……Env……………………..……Other(s)…

16. What other causes of accidents do you know?

…………………………………………………………………………………………

17. What has been done differently based on recommendations / corrective actions from accident investigations?

…………………………………………………………………………………………

18. What are the existing health and safety measures to prevent / reduce ASM accidents?

…………………………………………………………………………………………

18. What is the existing environmental management plans to reduce or eliminate ASM environmental incidents?..

19. Is ASM activity in this area or Ghana in general risky?.........

…………………………………………………………………………………………………

20. What is the average number of people involved in ASM activities in this area?......

Directly………………..Indirectly………………..Legal………………Illegal……

21. How often do you visit the ASM sites to check conformance?...............................

…………………………………………………………………………………………………

22. What age group is commonly seen in these areas of ASM operations?....................

23. Why do some people operate without license?...........

24. With you current numbers (human resource capacity), how are you able to coordinate monitor all the ASM activities in this area (both legal and illegal operations)?...
…………………………………………………………………………………………………
…

25. What can you say about ASM accidents in Ghana generally emphasizing on causes and prevention? ………………

Acknowledgement:…………………………………………………………………..

(Minerals Commission – Konongo)

8 APPENDIX 2.

<u>Visit to EPA – Sunyani</u>

1. What role does EPA play in Artisanal Small Scale Mining?

………………………………………………………………………………………………

2. Do you register their operations and provide Environmental permit too?..................

3. What consideration is given before permit is issued?..............

4. What common practice is used by the ASM operators and how does it impact on the environment?

………………………………………………………………………………………………5

. Does EPA regulate the activities of ASM and how often does the agency visit the ASM sites?

……………………………………………………………………………………………

6. How many registered ASMs do we have in the region? Do you know about the number of illegal ASMs too?

……………………………………………………………………………………………

7. What kind of support if any do you give to the ASM operators?....................

8. How often do you receive report of environmental damage by the ASM operations?..............

9. How do these environmental accidents/incidents reported to you?.................

10. Do you investigate these reports? What have been the most occurring immediate and basic causes?

……………………………………………………………………………………………

11. What other causes do you know?...

12. How is your monitoring of the Large scale mining operation different from that of ASM operations?..

13. Do you receive any form of report on regular basis from ASM operatives? What form does it take if any?..........

14. What has been done differently based on recommendations / corrective actions from environmental incident investigations………………

15. What can be done to prevent future environmental incidents / accidents from galamsey activities

Acknowledgement:…………………………………………………………………..

APPENDIX 3

Visit to ASSOCIATION OF SMALL-SCALE MINING OFFICE – Asankrangwa

1. How many members make up this group? …………………………

2. What are the main objectives of this association?..

3. How does this association relates with Galamsey stakeholders?.............................

4. Are all your members registered?..

5. How do you see the small scale mining registration process?........

………………………………………………………………………………………………

6. What kind of help do you get from MC, EPA, Police, Traditional Authorities, and Dist. Assembly?

………………………………………………………………………………………………

7. How do you predict a particular area for prospecting and possible gold mining?.......

8. What are the common mining methods employed in galamsey?............

………………………………………………………………………………………………

9. What are the steps involved?............

What instruments are involved?................................

10. What are the risks/ hazard associated with each step?...

………………………………………………………………………………………………

11. Do you have to give any report to give to MC, EPA, D/A etc?.........

12. Do you record accidents in your operation? What types of accident do you

frequently record?...

13. Do you have to comply with health and safety measures? What are some of the safety requirements to be complied with at the ASM sites? What punitive measures exist for breach of health and safety requirements? Has any ASM suffered such punitive measures yet?

……………………………………………………………………………………………

14. How often does accident occur among the member sites?.......................................

15. What has been the most occurring consequence of the reported accidents?.............

a) Fatalities……………….………..Disabling Injuries…………………………..……

Minor Injuries…………Property Damage……….Env…………………Others………

16. What are the most common causes of accidents in your area?................................

17. What are the existing health and safety measures to prevent / reduce ASM accidents?…………………………

18. What are the existing environmental management plans to reduce or eliminate ASM environmental incidents?..

19. Is ASM activity in this area or Ghana in general risky?..

20. What is the average number of people involved in ASM activities in this area?...

Directly……………Indirectly……………..Legal………..…Illegal……….…………

22. What age group is commonly seen in these areas of ASM operations?...................

……………………………………………………………………………………………..

23. Why do some people operate ASM without license?...

………………………………………………………………………………………………

25. What can you say about ASM accidents in Ghana generally emphasizing on causes and prevention? ……………………………………

Acknowledgement:…………………………………………………………..

(ASSM –)