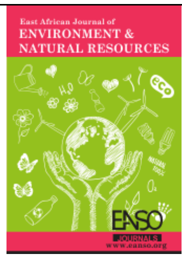

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Original Article

On the Margins of the Mining Economy: Occupational Health and Safety in Artisanal Scale Gemstone Mining in the Mwatate-Voi Area, Taita Taveta County, Kenya

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ABSTRACT

Artisanal gemstone mining in Kenya provides income and livelihoods to many locals in Taita Taveta County. However, little is known about the occupational safety and health issues encountered in this activity. This study investigated major occupational health and safety issues associated with artisanal gemstone mining using a variety of methods including key informant interviews, administration of questionnaires to mineworkers and direct observations at mining sites. Out of ninety-five (95) miners surveyed at ten (10) mining sites, sixty-eight (68) (71.6 %) had suffered injuries resulting in absence from work for days up to over a month. The major injury type was contusions (73.5 %). The main cause of injuries was tools/machinery handling (92.6 %). Only about twenty-seven (27) miners (28.4 %) used safety gear at work while twenty-nine (29) (30.5 %) had received any form of safety training. This study suggests that miners generally lack basic knowledge and education on the mitigation of occupational hazards associated with their work and basic tools/equipment for use in gemstone mining. Provision of education on and/or adequate enforcement of occupational health and safety regulations by relevant government agencies would improve the knowledge of miners on how to minimize occupational hazards.

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INTRODUCTION

The mining industry as a whole continues to be a significant economic sector for most nations globally (Groves et al., 2007). The industry significantly contributes to employment creation, supporting livelihoods and revenue generation to governments. Nonetheless, the industry is noted as one of the most hazardous in which people work hence occupational diseases, injuries and fatalities from the industry, are among the most expensive (Kecojevic et al., 2007).

Artisanal and small-scale mining (ASM); a sub-sector of the mining industry mostly practised in the global south (IGF, 2018), has been noted to play a significant role in providing employment and supporting livelihoods in most developing countries (Fisher et al., 2009; Shen and Gunson, 2006). According to ILO (1999), there were about 13 million people engaged in ASM and around 80 to 100 million dependents being supported by the sector as of 1999. The World Bank (2013) reports that there are about 100 million people who are dependent on ASM both directly and indirectly. In 2017, those directly involved in ASM were approximated to be 40.5 million indicating that numbers are ever increasing (IGF, 2018).

Despite the socio-economic benefits of ASM, it is accompanied by several environmental and socio-economic challenges in particular occupational safety and health hazards such as exposure to mercury, dust, silica and other toxic particulate matter and collapse of mines (Bansah et al., 2018; Hentschel et al., 2003; IGF, 2018). These challenges are attributed to weak governance, unskilled workforce, poor ventilation, long working hours, lack of safety gear, no health or life insurance, inadequate occupational safety and health training and education, high temperatures and the use of unsophisticated tools and techniques (Basu et al., 2015; de Oliveira and Ali, 2011; IGF, 2018; Malisa and Kinabo, 2005). Exposure to these hazards is associated with several occupational injuries and diseases not forgetting fatalities.

Occupational injuries include lacerations, contusions, fractures, multiple injuries, dislocations and suffocations while occupational diseases include emphysema, asthma, acute and chronic bronchitis, silicosis and pneumonia (Ayaaba et al., 2017; Basu et al., 2015; Calys-Tagoe et al., 2015; Nakua et al., 2019; Stemn, 2018). Other health conditions observed include decreased lung function, skin rashes, eye irritations, impaired hearing and impairment of renal function (Henry et al., 2017). Several studies have documented that the most experienced injury types are lacerations, contusions, fractures and multiple injuries which mainly affect the upper limbs, lower limbs and head (Calys-Tagoe et al., 2015; Elenge et al., 2013; Long et al., 2015; Stemn, 2018). There exist several mechanisms through which these injuries occur; the major ones being the use of machinery/tools, being hit by objects such as falling rocks, falling from height/level, suffocation and collapse of mines (Boniface et al., 2013; Kyeremateng-Amoah &

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Clarke, 2015; Long et al., 2015; Nakua et al., 2019; Stemn, 2018).

In Kenya, ASM involving gold panning, gemstone mining, harvesting of sand, gravel, clay and stone quarrying is carried out in various parts of the country and is a significant activity with an estimated population of 146,000 people in 2012 (AMDC, 2017; Barreto et al., 2018). The sector remains largely informal, yet it produces approximately 60% of the country's gemstones, most of its gold, quarry stones, and other construction materials (Barreto et al., 2018). According to Davies and Osano (2005), the ASM industry in Kenya is significant as it plays a crucial role in alleviating poverty through job creation though it is accompanied by several environmental and social consequences. The challenges being faced by ASM in Kenya include land ownership conflicts, inadequate geological data, occupational health and safety hazards, lack of strategies for mineral marketing, promotion and value-addition, inadequate institutional and human capacity, inadequate funding, obsolete infrastructure and low attraction and retention of technical experts, gender-related issues and child labour and lack of equity in sharing of the benefits accrued from mineral production between the local communities, County governments and the National Government (Barreto et al., 2018; Government of Kenya, 2016).

According to Rop (2014), artisanal gemstone mining which is a widely known activity in Kenya is dominated by ASM operators (both legal and illegal) who contribute to over 60 % of gemstone production annually. This activity dates back to 1971 when the first gemstones were discovered (Pardieu and Hughes, 2014). These gemstones are the green grossular garnet popularly known as the 'Tsavorite' discovered by a Scottish geologist; Campbell Bridges near Tsavo National Park (Pardieu and Hughes, 2014). The extraction methods utilized in the activity are both open-cast and underground methods with the underground (tunnelling) methods being the common ones (Rop, 2014). This activity in the Mwatate - Voi area in Taita Taveta County of Kenya has, for many decades, served as an important livelihood and income-generating activity undertaken by many people. Barreto et al. (2018) reported that the activity is a primary source of employment for about 57 % of people, well above agriculture (39 %), trading (35 %) and other activities in the area.

Despite these known benefits that the activity offers, there is limited research on the occupational safety and health issues that are faced in this activity. Previous studies (e.g. Barreto et al., 2018; Mwakumanya et al., 2016; Rop, 2014) have mainly focused on the economic potential and contribution of the sector in the area, and impacts on women in one of the gemstone mining zones (Kasigau zone). This study sought to investigate the occupational health and safety issues associated with artisanal small-scale gemstone mining in the Mwatate-Voi area in Taita Taveta County, Kenya.

The main objective of this study was to investigate the occupational health and safety issues associated with artisanal gemstone mining in the Mwatate-Voi area in Taita Taveta County. Specifically, the study aimed to identify the injury status of miners, the type of injuries sustained by injured miners, the causes of the injuries, the association between injury risk factors (background characteristics of miners) and injuries sustained by miners, and to observe compliance with the occupational health and safety requirements in the mining industry.

MATERIAL AND METHODS

Research Design

A cross-sectional study that employed mixed methods was adopted for this study. Mixed methods research design was utilised to not only help explain and show links between variables but also to make systematic descriptions, deductions and/or inferences based on data acquired (Kothari, 2004). The study was conducted between November 2018 and January 2019.

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Study area

The Mwatate-Voi area is located approximately 360 km Southeast of Nairobi (the capital of Kenya) in Taita Taveta County. The County covers an approximate area of 17,084.1 km^2 and nearly 62 % of this total area is occupied by the Tsavo National Park (Taita Taveta County Government, 2013) (Figure 1). Water bodies, ranches, wildlife sanctuaries, sisal plantations and Taita Hills forests occupy the remaining area (Rop, 2014). It is found within longitudes 37º 30' 00" and 39º 30'00" East and latitudes 2º 30'00" and 4º 30'00" South (Taita Taveta County Government, 2013). It is bounded by Kilifi and Kwale Counties in the East, Tana River, Makueni and Kitui in the North, Kajiado in the Northwest and the Republic of Tanzania in the Southwest (Taita Taveta County Government, 2013).

Administratively, it is subdivided into four sub-counties; Wundanyi, Mwatate, Voi and Taveta which are further subdivided into twenty County Assembly Areas, the lowest political units in the Kenya governance system (Taita Taveta County Government, 2013). The County's relief is undulating and rugged with an altitude ranging from 304 m to 2,208 m (Taita Taveta County Government, 2013). The lowlands (plains) are the major topographical feature within the Mwatate-Voi area. The annual average rainfall ranges from 350 mm to 900 mm with an average annual temperature of about 23 ºC (Taita Taveta County Government, 2013). The lower zones which are within the Mwatate-Voi area receive an average rainfall of 440 mm per year (Taita Taveta County Government, 2013).

The County has several vegetation cover types namely; montane mist forests, dry forests, woodlands, grasslands, riverine forests/swamps and bushland and thicket (Anyona and Rop, 2015). Common vegetation cover types in the Mwatate-Voi area are dry forests, woodlands, grasslands and riverine forests/swamps. Some of the dry forest species include *Tamarindus indica*, *Terminalia brownii*, and fig tree species, among others. Woodlands and grasslands species include acacia, commiphora and grass species such as *Themeda triandra* (Anyona and Rop, 2015). The main types of soils in the County are cambisols, ferralsols (common in the Mwatate-Voi area), luvisols, acrisols, arenosols, fluvisols and saline and sodic soils (NAAIAP, 2014).

The bulk of the County (Mwatate-Voi area) is found along the Mozambique Belt which stretches from Madagascar and Mozambique through Eastern Africa to Arabia (Pohl and Horkel, 1980) which hosts most of the gemstones and other industrial minerals. Some of the gemstones include ruby, tsavorite (green garnet), rhodolites, red garnets, yellow and green tourmaline and pink and blue sapphire (Rop, 2014).

The County had an estimated population of 284,657 in the 2009 census (Kenya National Bureau of Statistics, 2012). The main economic activities in the County are animal husbandry on ranches, ecotourism, small-scale subsistence farming, small and micro enterprises, large-scale mining and artisanal and small-scale mining (Rop, 2014). In addition, other residents are employees in various government departments and private sector institutions. In the Mwatate-Voi area, artisanal and small-scale mining is the chief economic activity (Barreto et al., 2018).

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Figure 1. Location of Taita Taveta County and the study sites, Kenya (Modified from World Resource Institute, 2019).

Study population, sampling procedure and sample size

The study population was the artisanal and small-scale gemstone miners who work at the different mining sites within the study area and key informants from the National government (Ministry of Mining and Petroleum-Mines and Geology office at the county level), the County Government, mine owners and National Environment Management Authority-County office.

The non-probability sampling design was used (Kothari, 2004). In this study, convenience sampling and purposive sampling were employed in selecting sampling units. The convenience sampling technique was used in selecting the miners who were found working at ten (10) purposively selected mining sites (Table 1). These mining sites were easily accessible as they were widely scattered in the remote study area. Besides, the owners of these sites had permitted the miners to participate in the study. The purposive sampling method was also used in selecting the key informants from the

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National government (Ministry of Mining and Petroleum; Mines and Geology office at the County level) and National Environment Management Authority-County office.

Table 1: Mining sites and location

Mining sites	GPS Location in decimal degrees	
	Latitude	Longitude
Amec	-3.58209	38.27770
Classic	-3.64755	38.37009
Chawia	-3.73407	38.37894
Fatuma	-3.75004	38.38983
Titus	-3.64471	38.37359
Davis Mining	-3.62387	38.29668
Mwangola	-3.65578	38.38263
Hardrock	-3.60245	38.29585
Ikua	-3.77967	38.42505
David Visram	-3.78336	38.44228

Data sources and collection methods

Data was gathered from both primary and secondary sources for the achievement of the set objective. Primary data sources included key informant interviews, direct observations, questionnaires and photography. Secondary data sources included scientific databases including Scopus and other non-scholarly reports from the internet. Data collection methods included key informant and in-person interviews, direct observations at mining sites and administration of questionnaires. The key informant and in-person interviews were done using semi-structured questions as a guide.

To address the common method bias associated with the use of questionnaires, we ensured that the study was endorsed by the management; and mine owners, the questionnaire was as brief as possible and contained simple and concise questions (Jordan and Troth, 2020; Podsakoff et al., 2012). Also, the respondents were explained how they would benefit from the study and that they would be anonymous (Podsakoff et al., 2012).

Ethical Considerations and Approval

Ethical clearance was sought from the Ethics Committee of the University of Ghana. This committee is tasked with the responsibility of ensuring that researchers of the institution follow ethical issues to ensure the safety and confidentiality of respondents. The committee also looks at data collection methods and any other issues related to the study. Clearance was given to the researchers upon meeting the requirements and satisfaction of the committee.

Eligible participants were made to understand that ethical clearance for the study was sought from the Ethics Committee of the University of Ghana and further approval was given by the County's Mines and Geological Office. These two separate documents were presented to the participants of the study as evidence of the official approval of the study and adherence to the study protocols. Prior to conducting the interviews, each eligible participant was presented with the participant consent form to allow for their decision regarding participation in the study. Ultimately, evidence of consent was given by signature on the consent form before an interview started.

Data processing and analysis

Data obtained from key informant interviews and direct observations at the mining sites were carefully analysed in terms of their content and relationship to possible occupational health and safety hazards. Data collected from administered questionnaires were, however, checked, coded and statistically analysed using SPSS software version

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24 (IBM, Armonk, NY, USA). Descriptive statistics (frequencies and valid percentages) were generated to summarize the categorical data. Binary logistic regression analysis was used to identify injury risk factors influencing injury occurrence among miners. For a better interpretation of the results, some of the data were classified into fewer categories.

RESULTS

Background characteristics of miners

Even though artisanal-scale gemstone mining is not entirely a male-dominated activity (Barreto et al., 2018), the study suggests that males make up the entire workforce of miners at most of the mining sites (Table 2). Miners of various age groups, typically from below 25 to over 38 years, were encountered. Most of the miners had attained primary (basic) education (57.9%) and about 68.4% of them were locals (born and raised in the study area). With regard to marital status, the majority of the miners were married (71.6%). Most of the miners (72.6%) had a mining experience of five or more years in artisanal gemstone mining within the study area and the majority of them (94.7%) undertook mineral extraction.

Table 2: Background characteristics of miners (n=95)

Characteristic	Number of Miners	Percentage
Sex		
Male	95	100
Female	-	-
Age group (years)		
< 25	13	13.6
25 – 31	25	26.3
32-38	24	25.3
Above 38	3	34.7
Education level		
No formal education	6	6.3
Primary	55	57.9
Secondary	32	33.7
Tertiary	2	2.1
Local resident		
Yes	65	68.4
No	30	31.6
Marital status		
Single	27	28.4
Married	68	71.6
Mining experience		
< 5yrs	26	27.3
≥ 5yrs	69	72.6
Activity undertaken by a mine worker		
Mineral extraction (digging)	90	94.7
Mineral processing	1	1.1
Others (security guarding and supervision of other miners)	4	4.2

Occupational health and safety

Major occupational health and safety issues observed at mine sites include non-existent signage, lack of personal protective equipment (PPE), inadequate knowledge of preventive measures and lack of training.

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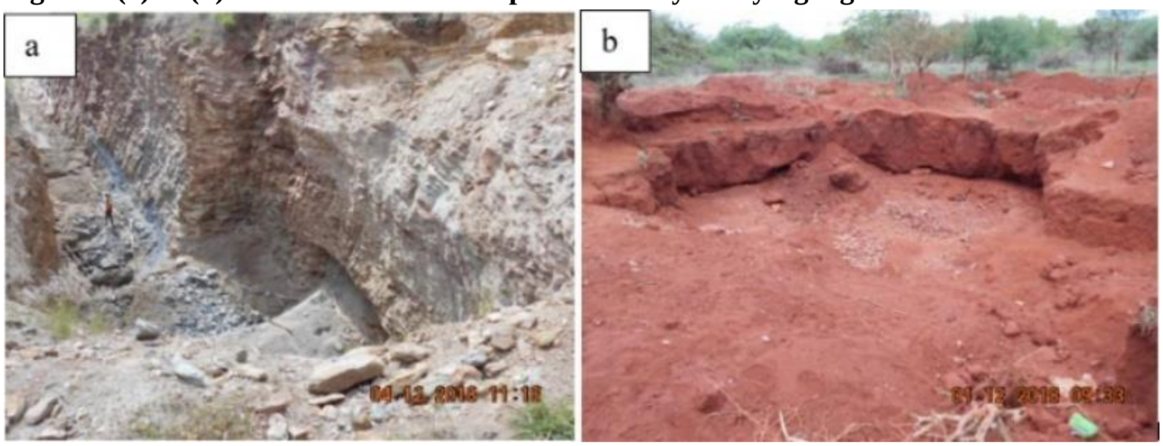
Non-existent precautionary safety signage

Observations made showed that there was no precautionary safety signage at mining sites. For instance, warning signs to help direct people to the locations of abandoned open pits, active mines and deep excavations were non-existent at all the mining sites studied. Besides, the practice of cordoning off active mines and deep excavations was non-existent (Figure 2).

Figure 2 (a) & (b). Active mines with no precautionary safety signage



Use of Personal Protective Equipment (PPE)

The majority of the miners (n=68, 72%) did not use Personal Protective Equipment (PPE) at work (Figure 3). This was corroborated by the Taita Taveta County Director of Environment (National Environment Management Authority) who explained as follows:

> *"During our inspections of these mines, we observe that the majority of the miners are without PPE. For a few of those that do use PPE, the PPE is not as appropriate as required. So, this is a big concern in this sector as these miners get exposed to several occupational hazards".*[1]

Direct field observations at the mining sites similarly showed that most miners do not use PPE when working (Figure 4). According to some miners, employers do not provide them with PPE as one artisanal miner explained:

> *"Our employer does not provide us with these PPE hence we end up working without them risking our safety and health. I do not have the capability to buy them by myself. Therefore, our employers should take this to be a serious issue."* [2]

Other miners were also of the opinion that there was no need to use PPE as argued by one of the miners:

> *"I don't see why I should use PPE as that is not of priority. What is of priority is to find the gemstones."*[3]

[1] Interview with the Taita Taveta County Director of Environment (National Environment Management Authority) on 22 November 2018.

[2] Interview with an artisanal gemstone miner at David Visram mine on 8 December 2018.

[3] Interview with an artisanal miner at Amec mine on 12 December 2018.

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Figure 3. Use of PPE by miners

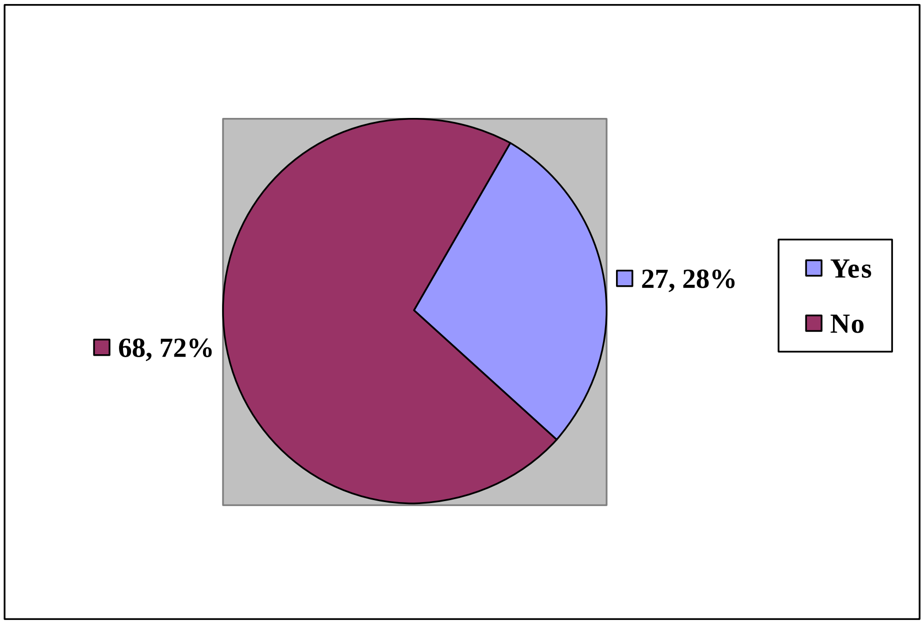

Figure 4 (a) & (b). Miners working without PPE at Chawia mine on 12th December 2018, Taita Taveta County, Kenya

Few miners (n=27, 28.4%) confirmed occasional use of safety gear at work (helmets, hand gloves and safety boots) but indicated that provision of such gear was often inadequate as one of them opined:

> *"Although our employer provides us with some PPE, they are inadequate as they are not provided regularly as required. So, we still end up not using them after some time exposing ourselves to occupational hazards."*[4]

Lack of skills training in occupational health and safety

Training in occupational health and safety measures was reported to be very minimal with few miners (n=29, 31%) (Figure 5) indicating to have received

[4] Interview with an artisanal gemstone miner at Classic mine on 8 December 2018.

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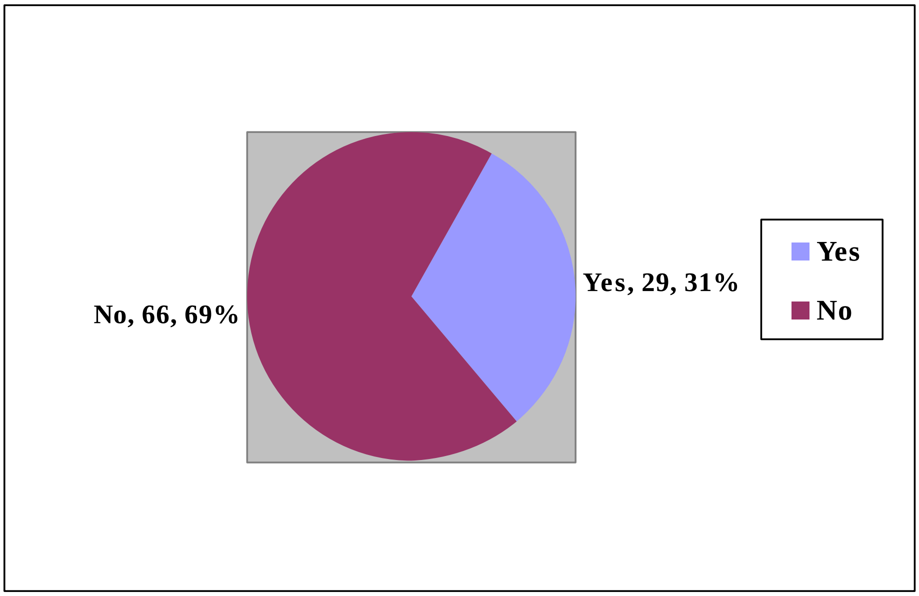
some training which, according to the miners, was done on a "one-off" basis by a non-governmental organization (NGO) or occasionally by a mine regulatory agency. This was supported by the County Mines and Geological Officer who opined:

"Though we do train miners on basic mining safety measures, this is occasionally done due to limited personnel at the County level and limited finances."[5]

Figure 5. Training in occupational health and safety measures



Injuries sustained by miners and their severity

An inquiry on the injuries sustained by miners showed that most of them had had some injuries. These were self-reported injuries as miners were asked to mention the injuries that they had sustained in the recent past (recall period of one year). Sixty-eight (68) miners representing 71.6% of the total miners had sustained an injury during mining operations over the past year (Table 3). The injury incidence rate was estimated to be 716 injuries per 1,000 workers indicating a high injury incidence rate among the miners. The most frequently reported injuries were contusions (73.5%) followed by cuts (17.6%) (Table 3). Musculoskeletal disorders falls, and loss of limb accounted for 4.4%, 3.0% and 1.5%, respectively, of the injuries that miners suffered. The main cause of injuries was the handling of tools/machinery (92.6%) (Table 3). Despite miners experiencing occupational hazards, only 29 of them representing 30.5% reported provision of insurance covers by their employers.

The number of work days lost by miners was used to show the severity of the injuries experienced by miners (ILO, 1999). Of the sixty-eight (68) injured miners, a majority (63.2%) lost 0-3 days of work (Figure 6). This suggests that most of the injuries were minor. Nevertheless, some miners lost 4-14 days (19.1%), 15-30 days (8.8%) and more than 30 days (8.8%) suggesting moderate, severe and very severe injuries, respectively.

[5] Interview with the County Mines and Geological Officer on 19 November 2018.

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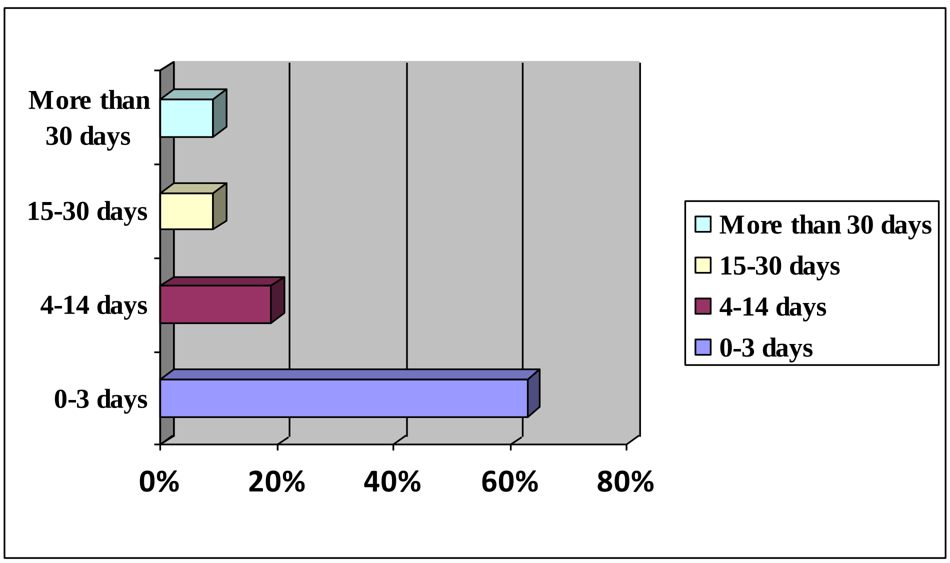
Table 3: Injury status, type and cause of injury (n=95)

Variable	Frequency	Percentage (%)
Injury status		
Yes	68	71.6
No	27	28.4
Type of Injury		
Cuts	12	17.6
Falls	2	3.0
Contusions	50	73.5
Musculoskeletal disorders (muscle sprains/strains)	3	4.4
Loss of limb (finger)	1	1.5
Mechanism of injury		
Machines/tools handling	63	92.6
Falling	2	3.0
Hitting by a falling object	3	4.4

Figure 6. Days of work lost by miners due to injury sustained (n=68)



Association of injury risk factors with injuries sustained by miners

The binary logistic regression results showed no statistically significant association between injury risk factors and injuries sustained by miners (Table 4). These risk factors including age group, level of education, marital status, activity undertaken by the miner, training on occupational safety and health, mining experience and PPE use had no statistically significant influence on injuries sustained by miners (p-values > 0.05) (Table 4).

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Table 4: Association of occupational injuries with risk factors (n=95)

Injury risk factor	Crude OR (95% CI)	P value
Age group		
0-24 years	1	
25-38 years	0.55 (0.08, 3.60)	0.53
39 + years	1.12 (0.16, 7.99)	0.91
Level of education		
Non-formal education	1	
Formal education	1.42 (0.21, 9.69)	0.72
Marital status		
Single	1	
Married	3.87 (0.79, 18.91)	0.09
Miner's activity		
Mineral extraction	1	
Others	0.28 (0.02, 3.50)	0.32
Mineral extraction & processing	0.00	1.00
Training on occupational health and safety		
Yes	1	
No	0.39 (1.13, 1.18)	0.10
Mining experience		
0-4 years	1	
5 +	0.43 (0.14, 1.32)	0.14
PPE Use		
Yes	1	
No	2.24 (0.67, 7.50)	0.19

Fatalities in artisanal gemstone mining

An inquiry into the occurrence of fatalities in artisanal gemstone mining revealed that a few do occur. These occur mainly due to the collapse of mines (or mine pits) and poor ventilation leading to asphyxiation. An interview with the County Mines and Geological Officer revealed that in 2015, a miner died in the Amec mine and another one in the Lilian Gems mines. Again in 2018, another miner died in the Chawia mine. The County Mines and Geological Officer noted:

> *"Fatalities do occur though a few. In 2015, my office confirmed the deaths of two miners who were working at the Amec and Lilian Gems mines. In 2018 too, a miner died at Chawia mine. These fatalities are mainly due to suffocation (arising from poor ventilation and indiscriminate use of explosives) and collapse of mines (arising from indiscriminate use of explosives and poorly engineered tunnels)."*[6]

DISCUSSION

Use of PPE by miners

Observations at the mine sites studied, together with responses obtained from miners in the questionnaires, indicate that majority of miners either did not use personal protective equipment (PPE) during work or were not provided PPEs by their employers in accord with other studies done in Kenya and other sub-Saharan African countries (Ajith and Ghosh, 2019; Bansah et al., 2016;

[6] Interview with the County Mines and Geological Officer on 19 November 2018.

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Boniface et al., 2013; Chimamise et al., 2013; Nakua et al. 2019). Lack of or inability to use PPEs during mining operations means that miners are exposed to occupational hazards such as physical and other injuries caused by inappropriate handling of working tools and machines, the collapse of mines, exposure to dust and other particulate matter (particularly silica) some of which could result in death. Chimamise et al. (2013), for example, reported that inadequate use of PPE in a mine in Zimbabwe had a significant influence on miners being injured. This emphasizes the importance of using appropriate PPE to prevent or mitigate the occurrence of injuries and diseases. Inadequate financial resources, lack of enforcement of mine safety regulations and inadequate training and education are some of the reasons for the limited use of PPE (Basu et al., 2015; Hentschel et al., 2002).

Training in occupational health and safety

Results from the present study suggest that only a few miners had received or undergone some training in occupational health and safety. The general lack of training in basic health and safety measures means many of the miners were not only exceedingly vulnerable but also were not equipped with basic skills, knowledge and experience to adequately mitigate incidences of potential work or mining-related hazards. This observation appears to be consistent with similar studies concerning training on mining safety measures in artisanal mining activities (Bansah et al., 2016; Calys-Tagoe et al., 2015; Elenge et al., 2013; Nakua et al., 2019). Training on occupational safety and health is fundamental as both mine owners and mine workers would be made aware of the valuable benefits of it in the mid to long term in preventing accidents which are extremely costly though it is costly in the short term (Hentschel et al., 2003; Kecojevic et al., 2007).

Injury incidence rate, type and causes of injuries

The injury incidence rate revealed in this study is 716 injuries per 1,000 workers. This incidence rate is close to that reported by Elenge et al. (2013) of 722 injuries per 1,000 workers which also indicated a very high injury rate among miners. On the contrary, other similar studies have reported lower injury rates compared to this study (Calys-Tagoe et al., 2015; Long et al., 2015). Calys-Tagoe et al. (2015) reported an injury rate of 235 injuries per 1,000 workers while Long et al. (2015) reported an injury rate of 455 injuries per 1,000 workers among artisanal and small-scale gold miners in Tarkwa, Ghana and Kejetia, Upper East Region of Ghana respectively.

The major type of injury that the miners suffered was contusions followed by cuts. Others included internal pains, falls and loss of limb. Similarly, other studies have found the common type of injury sustained by miners to be contusions (Elenge et al., 2013; Nakua et al., 2019). Nevertheless, this finding differs from that of other studies that document lacerations as the prevalent type of injury (Calys-Tagoe et al., 2015; Long et al., 2015; Stemn, 2018).

Injuries were mainly sustained because of improper handling of tools/machinery contributed by lack of skills training whereas some other injuries were due to accidental falls and/or impacts/hits by falling objects. This finding is consistent with that reported by other artisanal mining studies where the major mechanism of injury was the handling of tools/machinery (Chimamise et al., 2013; Elenge et al., 2013; Michelo et al., 2009; Nakua et al., 2019). Similarly, results from the analysis of mining data for 10 years showed that most injuries (ranging from 37% to 88% per year) were associated with tools/equipment (Kecojevic et al., 2007). However, a study by Boniface et al. (2013) reported that the major cause of injuries was falling rocks. Another study by Kyeremateng-Amoah and Clarke (2015) documented the collapse of mine pits and falls as the major underlying cause of injuries among miners.

Severity of injuries

The severity of injuries sustained by miners appeared to be manifested in the number of

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workdays that a miner lost. Nakua et al. (2019) carried out a study in four major mining districts in Ghana and reported that a few small-scale gold miners (32.9%) had suffered minor injuries. Our study, however, revealed that most miners usually suffered minor injuries which subsequently led to their absence from work for up to 3 days. This finding also differs from studies that revealed that the majority of the miners suffered moderate and severe injuries. For instance, Calys-Tagoe et al. (2015) reported that the majority of the miners (69%) had lost more than three workdays from injuries suffered in a study carried out in Tarkwa, Ghana. Elenge et al. (2013) also reported that 50.8% of the artisanal miners in Katanga, DRC, lost three or more workdays. Other than revealing the severity of the injury sustained, the number of workdays lost also reveals the socio-economic consequences associated with the injuries sustained. These consequences include working limitations and permanent disability, psychosocial challenges (such as emotional and mental stress, reduction of self-confidence and self-esteem, strain on social relationships and substance abuse) and economic costs which are both direct and indirect (such as medical expenses, loss of employment, depleted savings, reduction of income and loss of assets) (Ajith & Ghosh, 2019; Camm & Girard-Dwyer, 2004; Dembe, 2001; ILO, 2012; Kim, 2013; Lax & Klein, 2008; Van den Broek et al., 2011).

Influence of injury risk factors on occupational injuries sustained by miners

No statistically significant association was found between the injury risk factors (age, education level, marital status, activity undertaken by the miner, training on occupational health and safety, mining experience and PPE use) considered in this study and injuries sustained by miners. Calys-Tagoe et al. (2015) also reported no significant association between injuries and age of miners and training on occupational safety. Elenge et al. (2013) noted similar observations (i.e. no significant association) between age and mining experience of miners on one hand and injuries sustained by miners. Similarly, Nakua et al. (2019), reported no significant association between marital status, education level and mining experience of miners and injuries. On the issue of injuries experienced or sustained by miners and activities undertaken, our study differs from those of Calys-Tagoe et al. (2015) who rather reported a significant association between the two, i.e. injuries experienced and activities undertaken by miners.

Occurrence of fatalities in ASM

Our study revealed that a few fatalities do occur at artisanal gemstone mining sites resulting majorly from the collapse of underground mines and poor ventilation. Mghanga (2011) documents that in 2008, two miners died due to suffocation in the Amec mine while in 2009 one miner from the Wanjiru mine and another from the Classic mine died as they got buried when the mines they were working in collapsed, located within the study area. However, with no proper documentation or reporting system, the number of fatalities could be underestimated. Similar studies have also documented that the occurrence of fatalities in ASM is majorly due to mining machinery, collapse of mine pits, falls, being struck by a metallic object or rock and vehicle rollover (Bansah et al., 2016; Kyeremateng-Amoah and Clarke, 2015; Stemn, 2018).

Our study significantly contributes to existing literature and knowledge of occupational safety and health issues in the ASM sector specifically the artisanal gemstone mining sector in Kenya. With limited research into occupational safety and health issues in this sector, this study has revealed pertinent occupational safety and health issues that need to be addressed by government institutions and mine owners. Nevertheless, it was not without some limitations. First, the healthy worker partiality could have influenced the results as only the healthy workers would be present during a survey than those severely injured or ill (Li and Sung, 1999). Hence, the injury incidence could be underestimated as

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miners with very severe injuries could have missed work or stopped working due to the injuries experienced. Second, the sample size is not large enough to allow a broader generalization of the findings. Third, the findings of this study are only based on the artisanal gemstone miners in Kenya. Fourth, recall bias of respondents might have influenced the findings in that respondents retrospectively self-reported injuries sustained in the past year prior to the study. Thus, the injury incidence might be underreported due to respondents only recalling the most recent and severe injuries. Fifth, as a result of the smaller sample and nature of the data collected, this study relied mostly on descriptive statistics which do not provide in-depth insights.

CONCLUSION

In conclusion, this study suggests a fairly high incidence rate of injuries and mainly minor injuries sustained by artisanal gemstone miners in the Mwatate-Voi area in Kenya. The injuries, which occasionally resulted in fatalities, were mainly due to lack of and/or inappropriate handling of basic tools and equipment. Many of the injuries sustained were contusions and cuts. Background characteristics such as age and education seemed to have had no significant effect on injury incidence. Patronage and/or use of PPE as well as knowledge of mining safety and health training were both low.

With the formalisation of ASM in Kenya through the newly enacted Mining Act of 2016, there is an urgent need for relevant government institutions to ensure strict enforcement of environmental and occupational health and safety regulations (i.e. the Environmental Management and Co-ordination Act (1999) and the Occupational Safety and Health Act (2007) which may be critical in protecting miners and the society from the negative consequences of occupational hazards. The use of modern tools or equipment and frequent and comprehensive training appropriate use of such tools could be an intervention that could help reduce both occupational injuries and fatalities. Increased education and training in all aspects of mine health and safety coupled with effective use of appropriate PPE could also greatly help miners mitigate incidences relating to workplace short- and long-term impacts including injuries and attendant socio-economic implications. Further studies are needed to better comprehend occupational health and safety concerns in artisanal gemstone mining, particularly sufficiently funded longitudinal studies with larger sample sizes that would additionally provide more insight into this subject.

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