Implications of health, safety and environmental conditions on artisanal goldminers' self-protection at work in Ghana

Simon Appah Aram[1&2*], Benjamin M. Saalidong[3], Augustine Appiah[2]

[1]Research Center for Smart Mine and Intelligent Equipment, Taiyuan University of Technology, Taiyuan 030024, People's Republic of China

[2]College of Safety and Emergency Management Engineering, Taiyuan University of Technology, Taiyuan 030024, People's Republic of China

[3]Department of Geosciences, Taiyuan University of Technology, Taiyuan 030024, People's Republic of China

*Corresponding Author

Email: Samaran05yahoo.com (SAA)

Abstract

The nature of Artisanal mining in Ghana exposes its workers to various levels of health, safety and environmental (HSE) threats. These miners are mostly liable for their own HSE state at work. In an attempt to understand the HSE dynamics of artisanal miners, this study sought to assess the effect of HSE conditions on self-protection at work by artisanal goldminers in Ghana. A nested binary logistic regression model was fitted to a cross sectional survey of 500 artisanal goldminers while controlling for compositional and contextual factors. Of the HSE conditions, only health (OR= 1.653, p<0.001) and safety conditions (OR= 1.935, p<0.001) were robust in predicting self-protection in all three models. Goldminers who reported good health and safety conditions were more likely to fully protect themselves at work as compared to their counterparts who reported poor health and safety conditions. For compositional factors, female goldminers were 84% less likely to protect themselves. Miners who had senior high (OR= 1.759, p<0.001) or tertiary education (OR= 1.875, p<0.001) were more likely to protect themselves at work as compared to those with no formal education. Likewise, miners who undertook routine medical checkups (OR= 2.533, p<0.001) and the most experienced miners (OR= 2.734, p<0.001) were more likely to protect themselves at work. Counterintuitively, miners who earned more monthly income ($174 and above) were less likely to protect themselves. At the contextual level, miners who worked in non-production departments (OR= 2.001, p<0.001) and miners who worked in the medium scale subsector (OR= 5.311, p<0.001) were more likely to protect themselves at work. To increase

1

consciousness of self-protection in artisanal mining, there is the need for a national dialogue on how to improve HSE conditions and in the absence of legislation, the complexities in managing HSE in the sector needs to be decoupled to achieve fair and standard HSE conditions as championed by the World Health Organization.

Keywords: Artisanal mining; Environment; Goldmining; Health; Safety; Self-protection

Introduction

Artisanal goldmining is on the rise globally due to the rising prices for minerals and precious metals [1-2]. There are about 20 million people who work directly in artisanal mining, and over 80 million depend on it for their livelihood [1]. The goldmining industry in Ghana is one of the most important contributors to the nation's economy in terms of employment, direct and indirect revenues, exports, and investment [3]. Ghana is the largest gold producer in Africa and the seventh largest in the world [4]. As such, Ghana's mining sector attracts much attention from large scale, medium scale and small scale mining in both local and international fronts. In Ghana, artisanal gold mining accounts for over 20% of the nation's gold production and render employment to thousands of people mostly indigenous folks [5].

Despite these massive contributions, artisanal mining is generally associated with hazardous working conditions which affect the health, safety and environment (HSE) of its workers [6]. The sector is regarded as one of the HSE-critical domains coupled with dangerous operations within an environment where workers are exposed to abundant risks and hazards [7]. In Ghana, it is publicly known that artisanal miners operate in unsafe conditions which poses serious threats to everyone engaged in it [8]. The operations of artisanal miners present considerable amount of risk at an escalating rate [9]. The processes involved in this activity poses many occupational HSE hazards. The most common of these are mercury exposure, airborne silica dust and fumes generated from chiseling, drilling, blasting, grinding and crushing from pulverized ore, and noise from mining equipment [1].

The reliance on rudimentary techniques and the limited injection of capital investment in the sector places it at a disadvantage in terms of HSE conditions of its miners as compared to their largescale counterparts [10]. Accidents in artisanal mining occur frequently and are expected to occur [11]. However, most artisanal small scale (ASM) and medium scale (AMM) companies do not engage qualified HSE personnel or officers to manage these occurrences. Concession owners in this case sometimes work as supervisors or managers [12]. This place the miners in a more dangerous HSE situation emanating from the lack of in-depth appreciation of the processes and the risks involved with their operations, and accident causation models and theories [13].

Artisanal miners do not adhere to HSE measures and frequently suffer accidents, which sometimes lead to deaths, permanent disability, or reduced quality of life [14]. There are lack of safety regulations and enforcement, education and training, and functional infrastructure and equipment due to the absence of safety officers in the work place of some of these mines [5]. As a result, these miners are liable for their own health and safety at work. Adhering to standard HSE practices in artisanal mining is largely born out of individual's knowledge, beliefs and perception. It is acknowledged that, the lack of HSE culture in artisanal mining account for the majority of unsafe acts and conditions [15].

Achieving behavioral change in dealing with advanced policy issues like better HSE conditions and culture in artisanal mining, a comprehension of the main causes of the behavior is required. How miners conduct themselves, in this case self-protection at work, is decided by several factors which are entrenched in institutional contexts, socio-cultural norms and situations [16]. Definitely, in the absence of effective risk awareness in artisanal mining, it appears most miners are likely to evaluate risk based on their compositional attributes and working conditions at the workplace. Artisanal miners considered in this study were registered small scale and medium scale groups. This study sought to examine the factors that contribute to miners' decision to self-protect even in the absence of supervisory powers and regulations using a nested binary logistic regression. With a nested model, it is possible to determine the independent effect of the key predictors while controlling for the other independent variables.

Methods

Data collection and sampling procedure

This study is part of a research project that assessed the working conditions of goldminers in Ghana. The study area was the Western and Western North Regions of Ghana. In all, 20 artisanal mine sites were visited across the regions. Data collection took place from January 2018 to December 2019. The questionnaire was adapted and developed from other related studies, reviewed and accepted by the University of Cape Coast institutional review board in Ghana. The questionnaire was structured into three parts: compositional characteristics, contextual aspects and HSE quality measures. It comprised of closed-ended questions. The close-ended questions provided a variety of multiple-choice answers from which the respondents were given opportunity to tick as applicable.

To ensure its feasibility and content validity, the questionnaire was tested among 15 participants from Boboobo, a town with similar socioeconomic background to the respondents of the study. 15 participants were used for the pilot study because there were no prior information to base the sample size on. The pilot group was first asked to complete the questionnaire, and comment on the comprehensibility of the questions; this led to minor modifications of the questionnaire to improve understanding. Participants were randomly recruited for the survey. Due to ethical considerations and the reliance on self-reported indicators, participants who had worked for less than a month and participants less than 18 years were not recruited. Overall, 500 artisanal miners were recruited based on a 95% confidence interval, 50% estimated population proportion and at a 5% error rate.

Measures

Response variable

The Outcome variable in this study was self-protection at work by artisanal goldminers. Goldminers' job characteristics and environment were assessed to know the protective equipment required to protect themselves at work. Each miner was then observed and also asked about the protective equipment they use while working. If the miner missed any of the required equipment,

self-protection was indicated as "no" and if they used the complete set of equipment it was indicated as "yes".

Key predictor variables

The key predictor variables selected for this study were self-rated health conditions, safety conditions and environmental conditions of goldminers. Artisanal goldminers were asked to rate their HSE conditions. Each of the three indicators, with a series of questions, were evaluated as very poor (1), poor (2), good (3), very good (4), and excellent (5)". Total scores that were greater than 3 were considered as "good" and scores less than 3 were considered as "poor". For this study, "Health" referred to the functional status of gold miners. These include emotional wellbeing, physical fitness and rate of change in health status. "Safety" denotes the availability of appropriate personal protective equipment such as protective clothing, goggles, gloves, and institutionalization of practices such as safe disposal of hazardous materials, allowed levels of noise and protection against fall. "Environment" is generally described to encompass both physical and social scopes. These include but not limited to resources required for the job, perceptions of their workspace quality and setting, the physical surroundings and space availability.

Compositional and contextual factors

In this study, compositional factors referred to socio-demographic characteristics of artisanal goldminers. These factors included age, sex, marital status, education, years of experience, income and routine medical checkup. For routine medical checkup, goldminers were asked how many times they go for voluntary medical checkup in a year, miners who indicated a minimum of 1 was categorized as "Yes" and those who indicated none in a year were categorized as "No". The contextual factors for this study were work department and subsector of the goldminer. The selection of the compositional and contextual factors were based on literature, practical significance, theoretical relevance and parsimony.

Data analyses

The data was subjected to univariate, bivariate and multivariate statistical analyses to examine the relationships and proportions between factors that influence self-protection while controlling for theoretically relevant compositional and contextual factors. All statistical analyses were performed using Stata 15 (StataCorp, College Station, Texas) SE software at a Statistical significance of 0.05 and at a confidence interval of 95%.

Univariate and bivariate analyses

The univariate analysis was used to determine the percentages and distributions of the characteristics of the goldminers. Pearson chi-square and Cramer's V statistic were used to test and describe the relationship between the categorical independent variables and self-protection at work by artisanal goldminers. Pearson's chi-square is used to determine if two or more groups of samples are independent or not. Cramer's V statistic assesses the strength of the association among categorical variables. A complementary log-log bivariate regression was carried out to ascertain the "one-on-one" predictive relationship between the predictors and the dependent variable before the multivariate model was implemented.

Multivariate analyses

The relationship between self-protection and the HSE conditions of artisanal goldminers were determined using a nested binary logistic regression model. Logistic regression allows the model to be related to the response variable via a link function and by allowing the magnitude of the variance of each measurement to be a function of its predicted value under the assumption of binary response (Yes/No) [17].

Ethical statement

Ethical approval was sought from the Ghana Health Service ethical review board to conduct the study. The purpose of the study and other details were disclosed to the authorities and participants. Oral consent was sought from participants before the study started as required by the minerals commission of Ghana. Participants were not financially induced or coerced to take part in the study. It was explained to them that their participation was voluntary. They were also informed that the information provided will contribute to the improvement of their HSE conditions in Ghana

Results

Univariate analysis

Table 1 shows the distribution of respondents characteristics. Age of respondents ranged from 18 to 60 years. Years of experience of goldminers ranged from 1 to 52 years (M = 7.092, SD = 6.48256). Approximately 40% of participants worked in the AMM while 60% were from the ASM subsector. About 39% of goldminers indicated they had never gone for voluntary medical checkup or screening. Miners who worked in non-production departments (eg. administrators, gold buying etc) were 33% while 67% of them worked in production related departments (eg. drilling, crushing, underground, digging etc). Overall, 17.8 % of the goldminers reported poor health conditions while 82.2% reported good health conditions at the workplace. 49.8% further reported poor safety conditions with 52.2% indicating good safety conditions. For environmental conditions, 41.8% indicated poor conditions with the remaining 58.2% rating the environmental conditions at their work sites as good. 77.4% of all artisanal miners interviewed indicated that they protected themselves at work while the remaining 22.6% indicated otherwise.

Table 1. Demographic characteristics of respondents

Variables	Weighed Frequency	Weighed Percentage
Age		
18-24	166	33.2
25-34	239	47.8
35-54	67	13.4
Above 55years	28	5.6
Gender		
Male	432	86.4
Female	68	13.6

Marital Status		
Single	332	66.4
Married	168	33.6
Education		
No formal/ Primary/ Junior High	202	40.4
High school	129	25.8
Tertiary	169	33.8
Experience		
1-5years	287	57.4
6-10years	116	23.2
Above 10 years	97	19.4
Monthly Income ($)		
0-173	117	24.84
174-347	260	55.2
348-521	41	8.7
Above 521	53	11.25
Medical Checkup		
No	195	39
Yes	305	61
Department		
Production	335	67
Non-production	165	33
Sub sector		
ASM	300	60
AMM	200	40
Health conditions		
Poor	89	17.8
Good	411	82.2
Safety conditions		
Poor	249	49.8
Good	251	50.2
Environmental conditions		
Poor	209	41.8
Good	291	58.2
Self-protection		
No	113	22.6
Yes	387	77.4

Bivariate analysis

Measures of association

The contingency table (Table 2) presents the distribution of respondents characteristics and self-protection at work. Notably across subsectors, a larger proportion of AMM workers indicated they fully protect themselves at work while only 62.67% of ASM workers responded affirmative for self-protection at work. For gender, 81.71 % of males reported that they protect themselves at work while only 50% of women were affirmative when asked about wearing all protective equipment for their work. About 40.5% of goldminers who had no formal education or had primary education or junior high school education did not protect themselves at work. Across departments in the subsectors 67.16 % of miners who worked in production related departments did not protect themselves fully at work however, 98.18% of miners in the non-production related department protected themselves fully at work. 95.41% of goldminers who periodically undergo voluntary medical checkup indicated that they protected themselves fully at work while the remaining 4.59% did not self-protect.

Table 2 also presents Pearson's chi-square test of independence. Pearson's chi-square and Cramer's V statistics were used to determine whether the observed differences in self-protection at work and HSE conditions as well as compositional and contextual factors were independent. There were statistically significant associations between health conditions (χ^2 (1)= 89.7283, p<0.001), safety conditions (χ^2 (1)= 117.6817, p<0.001), environmental conditions (χ^2 (1) = 121.1232, p<0.001) and self-protection at work. This meant a rejection of the null hypothesis that HSE conditions did not affect the self-protection ability of artisanal goldminers in Ghana. Cramer's V statistic in this instance indicated moderately strong association.

For the compositional variables, age (χ^2 (3)= 26.6077, p<0.001), gender (χ^2 (1)= 33.7790, p<0.001), education (χ^2 (2)= 62.7493, p<0.001), experience (χ^2 (2)= 38.0661, p<0.001), monthly income (χ^2 (3)= 28.8984, p<0.001) and medical checkup (χ^2 (1)= 145.0125, p<0.001) had statistically significant association with self-protection at work. There was however, no association between marital status (χ^2 (1)= 1.8253, p=0.177) and self-protection. This suggests that marital status did not systematically differ with self-protection at work. Cramer's V statistics in this instance indicated weak association for age, gender, experience, monthly income and moderately strong association for education. There was however a strong association for medical checkup and self-protection.

With the contextual factors, department (χ^2 (1)= 60.8033, p<0.001) and subsector (χ^2 (1)= 93.0709, p<0.001) had statistically significant association with self-protection. This meant that self-protection systematically differs across departments and subsector of artisanal goldminers in Ghana. Cramer's V statistic indicated a moderately strong association between department, subsector and self-protection at work.

Based on Cramer's V statistics, the strength of the association between the categories of each predictor and self-protection at work in increasing order of magnitude, is as follows: age< monthly income< gender< experience< department< education< health conditions< subsector< safety conditions< environmental conditions< medical checkup.

Table 2. Percentage distribution of self-protection at work by predictor variables

Variable	Self-protection		Inferential statistics
	No (%)	Yes (%)	
Health conditions			$\chi^2(1)= 89.7283, p<0.001$
Poor	54 (60.67)	35 (39.33)	Cramér's V = 0.4236
Good	59 (14.36)	352 (85.64)	
Safety conditions			$\chi^2(1)= 117.6817, p<0.001$
Poor	107 (42.97)	142 (57.03)	Cramér's V = 0.4851
Good	6 (2.39)	245 (97.61)	
Environmental conditions			$\chi^2(1)= 121.1232, p<0.001$
Poor	98 (46.89)	111 (53.11)	Cramér's V = 0.4922
Good	15 (5.15)	276 (94.85)	
Age			$\chi^2(3)= 26.6077, p<0.001$
18-24	59 (35.54)	107 (64.46)	Cramér's V = 0.2307
25-34	42 (17.57)	197 (82.43)	
35-54	11 (16.42)	56 (83.58)	
Above 55	1 (3.57)	27 (96.43)	
Gender			$\chi^2(1)= 33.7790, p<0.001$
Male	79 (18.29)	353 (81.71)	Cramér's V = -0.2599
Female	34 (50)	34 (50)	
Marital status			$\chi^2(1)= 1.8253, p=0.177$
Single	81 (24.4)	251 (75.6)	Cramér's V = 0.0604
Married	32 (19.05)	136 (80.95)	
Education			$\chi^2(2)= 62.7493, p<0.001$
No formal/ Primary /Junior High	82 (40.59)	120 (59.41)	Cramér's V = 0.3543
Senior High	13 (10.08)	116 (89.92)	
Tertiary	18 (10.65)	151 (89.35)	
Experience			$\chi^2(2)= 38.0661, p<0.001$
1-5 years	93 (32.40)	194 (67.6)	Cramér's V = 0.2759
6-10 years	14 (12.07)	102 (87.93)	
Above 10 years	6 (6.19)	91 (93.81)	
Monthly Income ($)			$\chi^2(3)= 28.8984, p<0.001$
Below 174	38 (32.48)	79 (67.52)	Cramér's V = 0.2477
174-347	72 (27.69)	188 (72.31)	
348-521	1 (2.44)	40 (97.56)	
Above 521	2 (3.77)	51 (96.23)	
Medical Checkup			$\chi^2(1)= 145.0125, p<0.001$
No	99 (50.77)	96 (49.23)	Cramér's V = 0.5385
Yes	14 (4.59)	291 (95.41)	

Department			$\chi^2 (1)= 60.8033$, p<0.001	
Production	110 (32.84)	225 (67.16)	Cramér's V = 0.3487	
Non-production	3 (1.82)	162 (98.18)		
Subsector			$\chi^2 (1)= 93.0709$, p<0.001	
ASM	112 (37.33)	188 (62.67)	Cramér's V = 0.4314	
AMM	1 (0.50)	199 (99.5)		

Bivariate logistic regression of self-protection and predictor variables

For HSE conditions in the bivariate model as shown in Table 3, goldminers who reported good health conditions (OR= 3.88, p<0.001), safety conditions (OR= 4.421, p<0.001) and environmental conditions (OR= 3.915, p<0.001) were more likely to protect themselves at work as compared to their compatriots who reported poor health, safety and environmental conditions.

For the compositional factors, mine workers who were between the ages 23-34 (OR= 1.681, p<0.001), 35-54 (OR= 1.747, p<0.001) and above 55 years (OR= 3.221, p<0.001) had a higher chance of protecting themselves at work than mine workers between the ages of 18-24. Similarly, female miners were 59% less likely to protect themselves at work. Mine workers who had senior high school education (OR= 2.545, p<0.001) and tertiary education (OR= 2.484, p<0.001) were more likely to protect themselves as compared to those who had no formal or primary or junior high school education. The most experienced miners, 6-10 years (OR= 1.876, p<0.001) and above 10 years (OR= 2.470, p<0.001), had a higher chance of self-protection at work than their counterparts who had worked for 1-5 years. Artisanal goldminers who undertook voluntary periodical medical checkups (OR= 4.545, p<0.001) were more probable to protect themselves at work as compared to miners who never voluntarily went for medical checkups. For income, workers who earned between $348-$521 (OR= 3.302, p<0.001) and above $521 (OR= 2.914, p<0.001) monthly were more likely to protect themselves at work than mine workers who earned less than $174 monthly.

AMM miners (OR= 5.377, p<0.001) and miners who worked in non-production departments (OR= 3.598, p<0.001) were more likely to report self-protection at work as compared to their ASM counterparts and also miners who worked in production-related departments.

Table 3. Bivariate complementary log-log regression of Self-protection at work by artisanal goldminers

Variables	OR	Robust SE	p-value	Conf. Interval	
Health conditions (ref: Poor)					
Good	3.885	0.707	**<0.001**	2.720	5.549
Safety conditions (ref: Poor)					
Good	4.421	0.612	**<0.001**	3.370	5.799
Environmental conditions (ref: Poor)					
Good	3.915	0.506	**<0.001**	3.040	5.043
Age (ref: 18-24)					

25-34	1.681	0.217	**<0.001**	1.304	2.166
35-54	1.747	0.320	**0.002**	1.220	2.501
Above 55years	3.221	1.005	**<0.001**	1.748	5.936
Gender (ref: Male)					
Female	0.408	0.076	**<0.001**	0.284	0.586
Marital status (ref: Unmarried)					
Married	1.175	0.139	0.171	0.933	1.481
Education (ref: No formal / Primary/ Junior High)					
Senior High	2.545	0.378	**<0.001**	1.902	3.406
Tertiary	2.484	0.341	**<0.001**	1.898	3.251
Experience (ref:1-5 years)					
6-10 years	1.876	0.264	**<0.001**	1.424	2.473
Above 10 years	2.470	0.398	**<0.001**	1.801	3.387
Monthly Income (ref: below $174)					
174-347	1.142	0.162	0.351	0.864	1.508
348-521	3.302	0.963	**<0.001**	1.865	5.847
Above 521	2.914	0.708	**<0.001**	1.810	4.690
Medical checkup (ref: No)					
Yes	4.545	0.610	**<0.001**	3.493	5.914
Department (ref: Production)					
Non-production	3.598	0.573	**<0.001**	2.634	4.916
Subsector (ref: ASM)					
AMM	5.377	1.093	**<0.001**	3.611	8.008

Multivariate complimentary log-log regression model predicting self-protection at work by artisanal goldminers in Ghana

The multivariate relationship between self-protection at work by artisanal goldminers and the determinants are presented in Table 4. In the HSE condition model, health conditions (OR= 2.106, p<0.001), safety conditions (OR= 2.215, p<0.001) and environmental conditions (OR= 1.952, p<0.001) were all statistically significant predictors of self-protection at work. This meant that goldmine workers who reported good HSE conditions were probable to protect themselves at work as compared to those who reported poor HSE conditions.

When compositional factors were controlled for in model 2, interesting trends were noticed. It was conspicuous that the compositional factors had suppressed the relationship between self - protection and environmental conditions. This clearly indicates that compositional factors completely mediate this relationship. Health conditions (OR= 1.997, p<0.001) and safety conditions (OR= 2.809, p<0.001) remained robust in predicting self-protection at work. In the same compositional model, gender, education and medical checkup were statistically significant in predicting self-protection at work. Female goldmine workers were 62% less likely to fully protect themselves at work as compared to their male co-workers. Also, artisanal goldminers who had senior high (OR= 1.974, p<0.001) or tertiary education (OR= 2.585, p<0.001) were more probable to protect themselves at work as compared to miners with no formal or primary or junior

high school education. Likewise, miners who regularly went for medical checkup (OR= 2.153, p<0.001) were more likely to protect themselves at work than miners who did not go for checkups. Age and marital status had no statistically significant association with self-protection. Monthly income was not a significant predictor for self-protection unless for those who earned between $174-$347 were 59% less likely to protect themselves as compared to those who earned less than $174 monthly. Similarly, miners who had worked for more than 10 years (OR= 2.787, p<0.001) in the mining sector were more probable than their counterparts who had just 1-5 years' experience to protect themselves at work. Miners who had worked for 6-10 years were however not a significant predictor.

In model 3, where contextual factors were controlled for, health (OR= 1.653, p<0.001) and safety (OR= 1.935, p<0.001) conditions were still robust in predicting self-protection at work just as observed in model 1 and 2. For the compositional factors, the relationship between gender, education, routine medical checkup and self-protections at work remained robust and persisted. In this same model, a new relationship between monthly income and self-protection emerged, indicating mediation in the contextual model. Miners who earned $174-$347(OR= 0.400, p<0.001), $348-$521 (OR= 0.204, p<0.001) and above $521(OR= 0.294, p<0.001) were all less likely to protect themselves as compared to miners who earned less than $174. For the contextual factors, department (OR= 2.001, p<0.001) and subsector (OR= 5.311, p<0.001) were statistically significant in predicting self-protection at work. In this instance, artisanal miners who worked in non-production areas and those in AMM subsector were more likely to protect themselves at work as compared to their production department and ASM counterparts.

Table 4. Multivariate complementary log-log regression model predicting Self-protection at work by artisanal gold mine workers

Variables	Model 1: HSE Conditions					Model 2: HSE Conditions + Compositional factors					Model 3: HSE Conditions +Compositional +Contextual factors				
	OR	Robust SE	p-value	Conf. Interval		OR	Robust SE	p-value	Conf. Interval		OR	Robust SE	p-value	Conf. Interval	
Health conditions (ref: Poor)															
Good	2.106	0.408	**<0.0001**	1.440	3.079	1.997	0.486	**0.004**	1.240	3.217	1.653	0.408	**0.042**	1.019	2.680
Safety conditions (ref: Poor)															
Good	2.215	0.443	**<0.0001**	1.497	3.279	2.809	0.753	**<0.0001**	1.661	4.750	1.935	0.593	**0.031**	1.062	3.528
Environmental conditions (ref: Poor)															
Good	1.952	0.377	**0.001**	1.337	2.850	1.017	0.225	0.939	0.660	1.569	0.868	0.209	0.555	0.542	1.390
Age (ref: 18-24)															
25-34						0.917	0.200	0.693	0.598	1.407	0.864	0.210	0.548	0.537	1.391
35-54						0.977	0.332	0.945	0.502	1.902	0.926	0.321	0.824	0.469	1.827
Above 55 years						1.389	0.760	0.548	0.475	4.061	1.533	0.799	0.413	0.552	4.259
Gender (ref: Male)															
Female						0.374	0.082	**<0.0001**	0.243	0.574	0.157	0.064	**<0.0001**	0.071	0.350
Marital Status (ref: Single)															

Variable					B	SE	p	CI	CI	OR	SE	p	CI	CI
Married					1.126	0.254	0.598	0.724	1.753	1.058	0.261	0.820	0.652	1.715
Education (ref: No Formal/ Primary/ Junior High)														
Senior High					1.974	0.433	**0.002**	1.284	3.035	1.759	0.404	**0.014**	1.121	2.759
Tertiary					2.585	0.585	**<0.001**	1.658	4.028	1.875	0.556	**0.034**	1.049	3.352
Experience (ref: 1-5years)														
6-10years					1.420	0.298	0.095	0.941	2.144	1.343	0.321	0.217	0.840	2.147
Above 10 years					2.787	0.784	**<0.001**	1.606	4.836	2.734	0.792	**0.001**	1.550	4.824
Monthly Income (ref: below $174)														
174-347					0.408	0.101	**<0.001**	0.252	0.661	0.400	0.121	**0.003**	0.220	0.725
348-521					0.530	0.215	0.118	0.239	1.175	0.204	0.121	**0.007**	0.064	0.653
Above 521					0.552	0.198	0.098	0.273	1.116	0.294	0.140	**0.010**	0.116	0.746
Medical checkup (ref: No)														
Yes					2.153	0.371	**<0.001**	1.536	3.019	2.533	0.509	**<0.001**	1.708	3.755
Department (ref: Production)														
Non-production										2.001	0.577	**0.016**	1.137	3.521
Subsector (ref: ASM)														
AMM										5.311	3.282	**0.007**	1.581	17.833

Discussion

This study looked at the independent effects of HSE conditions, compositional and contextual factors on self-protection at work by artisanal goldminers in Ghana. Gold mining continues to be one of the most dangerous occupations worldwide albeit its socio-economic benefits. The artisanal goldmining industry in Ghana has had its fair share of morbidities and mortalities. Managing HSE in artisanal mining in Ghana is complex and multifaceted. Although developing and enforcing relevant HSE regulations is a major factor in managing the threats in mining, Ohnishi [18] reported that development and implementation of such policies have lagged behind in low-and-middle income countries just as it is in Ghana. In this instance, goldminers ability to perceive danger and act towards the perceived danger in a positive way is key to ensuring a healthy and safe workforce. Usually, under close supervision, most goldminers in artisanal mining tend to adhere to HSE best practices, this is however not the case when they are either out of sight of such supervisory controls or when such controls do not exist [4]. In this case, it is either the goldminer has an instinctive desire for self-protection or they let loose most of their protective equipment. It is widely reported that mine workers who have high compliance to HSE standards are less likely to report occupational related health challenges [16]. To understand this phenomenon, this study was carried out to identify the contributions of HSE conditions, compositional attributes and the contextual factors of artisanal miners to self-protection at work.

Our findings revealed that, of the HSE conditions of goldminers in Ghana, environmental conditions had very minimal impact (mediated by compositional and contextual factors) on goldminers decision to protect themselves at work. It was also established that health conditions and safety conditions were significant predictors of self-protection at work. The significant statistical relationships between health conditions, safety conditions and self-protection were robust and persisted in all the three models. This meant that artisanal miners who rated their health and safety conditions as good were more likely to protect themselves, all the time, at work as compared to those who rated their health and safety conditions as poor. Surprisingly, goldminers who worked under poor health and safety conditions were inclined to not protect themselves regularly at work. Ordinarily, it is expected that people who work in poorer conditions will instinctively protect themselves but this was not the case in this study. It is known that exposure to multiple hazards has the tendency of clouding one's judgment of risk, usually, based on factors such as years of experience in the mining industry and the perceived potential consequences of the risk [19]. Artisanal goldminers in Ghana, who work under poor health and safety conditions, have been repeatedly exposed to hazards of their occupation to the extent that most of them no longer perceive such risks to be high. Some goldminers were visibly seen entering tunnels without helmets while others were seen in the same instance without protective boots. Some were also observed working around crushers without nose masks but rather with pieces of rags tied around the nose just below the eyes. When asked about their choices, some claimed that they had been doing it for several years without any health consequence. Others too made known the fact that there were unavailable PPEs and even when available they were inadequate.

Amongst the compositional factors, gender, education, monthly income, years of experience and medical checkup were significant in predicting self-protection. However, age and marital status were not significant predictors. These findings are similar to [20, 21, 22, 23], who posited that, compositional factors such as gender, education, monthly income and experience affects miners attitudes and their concepts of health and safety risks.

In the artisanal goldmining industry in Ghana, it is known that gender discrimination exists, especially in the ASM subsector. The discrimination comes in the form of unequal access to resources (financial and protective equipment). Female goldminers in this study were less probable to protect themselves as compared to their male counterparts. This finding is supported by [24] who discovered that of the 75.3% of artisanal miners who had PPE's for self-protection at work in the Tarkwa area, 68.7% was for men as compared to 31.3% for women. This meant that the companies' health and safety policies favored men hence discriminating against women. Some female respondents in this study indicated that some female colleagues had been relegated to departments perceived as "not dangerous" hence the refusal to provide adequate protective equipment. It was also noted that because of this decision to relegate them, most women were not paid enough to acquire their own protective equipment. Also, some female AMM workers who worked in offices were seen with little or no protective apparels.

Our findings also indicated that artisanal miners who had senior high and tertiary level education were more likely to protect themselves at work. This finding is similar to [25] and [11] who reported that educated people perceived higher risk than the less educated. This is probably due to the fact that education increases goldminers access to information on hazards and risk at the workplace.

Our study also found that miners who earned more income were less likely to protect themselves at work as compared to those who earned the least. Artisanal miners who earned $174-$347, $348-$521 and above $521 monthly were less likely to protect themselves as compared to their counterparts who earned below $174. Counterintuitively, goldminers who earned more were expected to protect themselves as compared to those who earned less. This is because high salary is a function of higher education in most cases and as such people who earn more are normally expected to know and do better. In this case, workers who earned less than $174 monthly were rather concerned about their health and safety at work. It could however be argued that goldminers who earned less were less likely to afford proper health care in case of an unforeseen health outcome. This was enough reason to use available resources to ensure proper protection at work by the least paid artisanal miners.

Goldminers who had worked for more than 10 years (most experienced) were more likely to protect themselves at work as compared to those who had worked for less than 5 years (least experienced). This could mean that experienced miners were more aware of and had accumulated knowledge of the risks associated with their work. Ahadzi et al. [26] reported that old workers are usually more compliant and have positive HSE culture than younger workers. Age however is a function of experience. Lombardi et al. [27] also found that younger inexperienced workers were less likely to protect themselves at work. Inexperienced workers lack the knowledge and discipline to keep themselves protected all the time albeit the poor HSE conditions some of these mine sites have. Most experienced goldminers in their long working years had witnessed colleagues, family and friends lose their lives or livelihoods from HSE accidents. Some had also experienced such accidents themselves.

On the contextual level, artisanal goldminers who worked in non-production related departments like gold buying, supervisors and administrators were more likely to protect themselves as compared to those in production related areas like loading boys, equipment operators, drillers, load carriers, panners and washers. It is well documented that experienced and educated artisanal miners avoid perceived dangerous department in the sector [4, 12, 16]. This suggest that most of them are found in the non-production departments. Such category of miners are known to be HSE conscious than the inexperienced, young and uneducated goldminers who prefer working in the dangerous areas where strength and brute force is required [26]. Miners with such characteristics are reckless and mostly non-compliant of HSE regulations.

Also, miners in the ASM subsector were less likely to protect themselves as compared to their AMM counterparts. The reliance on rudimentary techniques and the lack of investment in the small scale subsector exposes miners to various degrees of risks and hazards [4]. This however has the tendency to influence miners to underestimate risks and hazards. Some small scale miners in this study revealed that they do not use the required protection because they had done that for a long time without any consequences. Veiga and Fadina [28] in their study also reported that concession owners and workers in the small scale subsector are profit driven and therefore did not care about the HSE conditions of their workplace or themselves. It is however not surprising that miners in the small scale subsector are less likely to protect themselves at work as compared to their counterparts in the medium scale subsector whose owners and workers think of the sustainability of their jobs.

Overall, artisanal goldmining sites with poor HSE conditions have workers who are less likely to protect themselves at work. The contextual and compositional attributes of these miners

mediate some of the relationships. One of the limitations of the study is the reliance on self-reported measures to assess the likelihood of self-protection at work. This problem has been widely documented but it is established that the extent of the supposed distortions may be exaggerated [29]. It has also been well documented in literature that self-reported measures have proven to be effective for HSE studies [30]. The findings of this study showed a clear relationship between HSE conditions and self-protection at work. The evaluation of factors that influence self-protection provides a useful feedback to employees, HSE officers, managers, concession owners, NGO's and policy makers in addressing the HSE menace in artisanal mining. In the absence of legislation, there is the need to decouple the complexities in managing HSE in artisanal mining to achieve fair and standard HSE conditions as championed by the world Health Organization. Additionally, to increase consciousness of self-protection in artisanal mining, there is the need for a national occupational health and safety policy, interventions and health promotion campaigns for better HSE conditions in artisanal mining. The findings of this study could also provide an alternative or options for the monitoring, assessment, evaluation and, application and targeting of HSE interventions in the sector.

Conclusion

The effect of HSE conditions on artisanal goldminers self-protection at work was assessed while controlling for relevant compositional and contextual factors. Goldminers who reported good health and safety conditions were more likely to fully protect themselves at work as compared to their counterparts who reported poor health and safety conditions. Female goldminers were less likely to protect themselves likewise, miners who had senior high or tertiary education. Miners who undertook routine medical checkups and the most experienced miners were also more likely to protect themselves at work. Counterintuitively, miners who earned more income monthly were less likely to protect themselves. Across departments and subsector, miners in non-production departments and miners who worked in the medium scale subsector were more likely to protect themselves at work. The outcome of this study provides insights into the dynamics of the current negative HSE practices and state in the artisanal mining sector and may help in developing programs to improve the HSE culture in the sector. There are a number of adverse health implications for people who do not protect themselves in the gold mining industry, suggesting the need for a national occupational health and safety policy, interventions and health promotion campaigns, for better HSE conditions in artisanal mining. To increase consciousness of self-protection in artisanal mining, there is the need for a national dialogue on how to improve HSE conditions and in the absence of legislation, the complexities in managing HSE in the sector needs to be decoupled to achieve a fair and standard HSE conditions.

References

1. Long RN, Sun K, Neitzel RL. Injury risk factors in a small-scale gold mining community in Ghana's Upper East Region. International journal of environmental research and public health. 2015 Aug;12(8):8744-61.
2. Basu N, Clarke E, Green A, Calys-Tagoe B, Chan L, Dzodzomenyo M, Fobil J, Long RN, Neitzel RL, Obiri S, Odei E. Integrated assessment of artisanal and small-scale gold

mining in Ghana—Part 1: Human health review. International journal of environmental research and public health. 2015 May;12(5):5143-76.

3. Ghana Chamber of Mines. Mining industry statistics and data. 2009 (accessed 11.12.20.). Retrieved from http://ghanachamberofmines.org/wp-content/uploads/2020/07/2019-Mining-Industry-Statistics-and-Data-for-Ghana.pdf

4. Aram, S. A., Osei Lartey, P., Amoah, S. K., & Appiah, A. Examining subsector based inequalities in health, safety and environmental conditions of gold miners in Ghana. SSRN Electronic Journal. 2020. 10.2139/ssrn.3757491.

5. Bansah KJ, Yalley AB, Dumakor-Dupey N. The hazardous nature of small scale underground mining in Ghana. Journal of Sustainable Mining. 2016 Jan 1;15(1):8-25.

6. Ayaaba E, Li Y, Yuan J, Ni C. Occupational respiratory diseases of miners from two gold mines in Ghana. International journal of environmental research and public health. 2017 Mar;14(3):337.

7. Stemn E. Analysis of injuries in the Ghanaian mining industry and priority areas for research. Safety and health at work. 2019 Jun 1;10(2):151-65.

8. Osei L, Yeboah T, Kumi E, Antoh EF. Government's ban on Artisanal and Small-Scale Mining, youth livelihoods and imagined futures in Ghana. Resources Policy. 2021 Jun 1;71:102008.

9. Wireko-Gyebi RS, King RS, Braimah I, Lykke AM. Local knowledge of risks associated with artisanal small-scale mining in Ghana. International Journal of Occupational Safety and Ergonomics. 2020 Aug 27:1-8.

10. Calys-Tagoe BN, Ovadje L, Clarke E, Basu N, Robins T. Injury profiles associated with artisanal and small-scale gold mining in Tarkwa, Ghana. International journal of environmental research and public health. 2015 Jul;12(7):7922-37.

11. Fadlallah MA, Pal I, Hoe VC. Determinants of perceived risk among artisanal gold miners: A case study of Berber locality, Sudan. The Extractive Industries and Society. 2020 Apr 1;7(2):748-57.

12. Aram SA, Lartey PO, Amoah SK, Appiah A. Gold eco-toxicology: Assessment of the knowledge gap on the environmental and health effects of mercury between artisanal small scale and medium scale gold miners in Ghana. Resources Policy. 2021a Aug 1;72:102108.

13. Joe-Asare T, Amegbey N, Stemn E. Human Factor Analysis Framework for Ghana's Mining Industry. Ghana Mining Journal. 2020 Dec 31;20(2):60-76.

14. Wadi E, Alredaisy S. Socioeconomic and environmental implications of traditional gold mining in Sudan: The case of Barber Locality, River Nile State. Am Based Res J. 2015;4(7):1-1.

15. Opoku FK, Kosi I, Degraft-Arthur D. Enhancing Workplace Safety Culture in the Mining Industry in Ghana. Ghana Journal of Development Studies. 2020 Oct 23;17(2):23-48.

16. Armah FA, Boamah SA, Quansah R, Obiri S, Luginaah I. Unsafe occupational health behaviors: understanding mercury-related environmental health risks to artisanal gold miners in Ghana. Frontiers in Environmental Science. 2016 Apr 25;4:29

17. Aitkin MA, Aitkin M, Francis B, Hinde J. Statistical modelling in GLIM 4. OUP Oxford; 2005.

18. Ohnishi M, Tembo B, Nakao R, Matsuura E, Fujita W. Factors associated with self-rated health among mineworkers in Zambia: a cross-sectional study. Tropical medicine and health. 2021 Dec;49(1):1-1.

19. Didla S, Mearns K, Flin R. Safety citizenship behaviour: A proactive approach to risk management. Journal of Risk Research. 2009 Jun 1;12(3-4):475-83.
20. Wachinger G, Renn O, Begg C, Kuhlicke C. The risk perception paradox—implications for governance and communication of natural hazards. Risk analysis. 2013 Jun;33(6):1049-65.
21. Marcon A, Nguyen G, Rava M, Braggion M, Grassi M, Zanolin ME. A score for measuring health risk perception in environmental surveys. Science of the total environment. 2015 Sep 15;527:270-8.
22. Qasim S, Khan AN, Shrestha RP, Qasim M. Risk perception of the people in the flood prone Khyber Pukhthunkhwa province of Pakistan. International Journal of Disaster Risk Reduction. 2015 Dec 1;14:373-8.
23. Sana A, De Brouwer C, Hien H. Knowledge and perceptions of health and environmental risks related to artisanal gold mining by the artisanal miners in Burkina Faso: a cross-sectional survey. The Pan African Medical Journal. 2017;27.
24. Dinye RD, Erdiaw-Kwasie MO. Gender and labour force inequality in small-scale gold mining in Ghana. International Journal of Sociology and Anthropology. 2012 Dec 31;4(10):285-95.
25. Macias T. Environmental risk perception among race and ethnic groups in the United States. Ethnicities. 2015 Mar;16(1):111-29.
26. Ahadzi DF, Afitiri AR, Ahadzi E. Organizational safety culture perceptions of healthcare workers in Ghana: A cross-sectional interview study. International Journal of Nursing Studies Advances. 2021 Nov 1;3:100020.
27. Lombardi DA, Verma SK, Brennan MJ, Perry MJ. Factors influencing worker use of personal protective eyewear. Accid Anal Prev. 2009;41(4):755-762.
28. Veiga MM, Fadina O. A review of the failed attempts to curb mercury use at artisanal gold mines and a proposed solution. The Extractive Industries and Society. 2020 Jul 21; 7(3), 1135-1146
29. Wagner, J. A., & Crampton, S. M. (1993). Percept-percept inflation in micro organizational research: An investigation of prevalence and effect. Academy of Management Proceedings, 1993(1), 310–314
30. Siu OL, Phillips DR, Leung TW. Age differences in safety attitudes and safety performance in Hong Kong construction workers. Journal of Safety Research. 2003 Apr 1;34(2):199-205