PRINT: ISSN 0970-9274 ONLINE: ISSN 2456-6608
J Hum Ecol, 72(1-3): 104-115 (2020)
DOI: 10.31901/24566608.2020/72.1-3.3278

Sustainable Approach in the Assessment of Safety and Environmental Regulatory Compliance during Mining Activities

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KEYWORDS Environmental Factors. Mining. Noncompliance Effects. Regulatory Systems. Safety Factors

ABSTRACT Optimal resource extraction involves balancing economic, environmental and social aspects. Even though there are regulatory mechanisms, safety anomalies and environmental pollution have persisted during mining activities in Nigeria. The study aims at developing an approach for evaluating safety and environmental regulatory compliance during mining activities, based on effects of noncompliance and having compliance issues. Cross-sectional survey design was used in collecting data from miners operating within active mining sites in Ebonyi State, Nigeria. Results indicate that prevalence of noncompliance effects had a four-component structure, while factorial prediction was a good-fit for having compliance issues. The proposed approach integrates dimensions of noncompliance effects with factors predicted having compliance issues during mining activities. The approach can help mining companies, governments and mining communities in Africa improve safety and environmental regulatory compliance.

INTRODUCTION

Natural resources are vital to sustaining life on earth. The principles of sustainable development provide guidance on mining activities, by striking a balance in environmental, economic and social development (Endl et al. 2019). Therefore, sustainable mining implies optimal environmental resource management, realistic economic growth and social justice (Alves et al. 2020). Mining activities provide economic base for many communities in sub-Saharan Africa. With huge proven deposits of limestone, iron ore, granite, barites, gold, lead/zinc, among others, the mining sector has potential to spur economic growth in Nigeria (Obaje 2009; KPMG Report 2017). In Ebonyi State, mining activities are an important source of government revenue with more than 1.4 million metric tons of granite, lead/zinc, limestone and laterite produced in 2018 alone (National Bureau of Statistics 2019).

Currently, Nigeria's policy framework for safety and environmental compliance during mining activities stems mainly from the Nigeria Mineral Mining Act of 2007 (NMMA 2007). Nigeria's Ministry of Mines and Steel Development (MMSD) is saddled with enforcing the country's policy framework through MMSD's mines inspectorate department (general oversight and safety compliance), mines environment and compliance department (enforcing environmental standards) and artisanal/small-scale mining department (responsible for small-time miners with lower capacity) (KPMG Report 2017). Section 17 of the Nigerian Minerals and Mining Act 2007 places safety regulatory enforcement under the mines inspectorate department. Similarly, Section 18 of Nigerian Minerals and Mining Act No. 20 of 2007 empowers the mines environmental compliance department to enforce all environmental statutes, while Section 19 establishes an environmental committee in each of Nigeria's thirty-six states, to ensure that stakeholders comply with applicable environmental protection measures. In addition, Parts IV (mines health and safety) and V (mines environmental management) of the Nigeria Mineral Mining Regulations of 2011 provide specific guidelines on the safety and environmental management during mining activities in Nigeria (NMMR 2011). Nonetheless, availability of a safety and environmental policy framework for mining activities does not essentially mean it will be complied with

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(Söderholm et al. 2015; Liu et al. 2019). Therefore, it is necessary to identify prevalence of safety and environmental noncompliance in Nigeria, as well as factors affecting regulatory compliance during mining activities.

Prevalence of Safety and Environmental Regulatory Noncompliance in Nigeria

Undertaking sustainable mining can be disconcerting, particularly in terms of complying with international best practices (Pactwa et al. 2018). On that note, mining activities in Nigeria have been linked to air, soil and water pollution due to excessive release of heavy metals and other physicochemical parameters (Dike et al. 2019; Kalu and Ogbonna 2019; Adewumi and Laniyan 2020). Furthermore, low regulatory compliance indicates a dysfunction in the enforcement of safety regulations in Nigeria (Umeokafor et al. 2014a; Umeokafor 2019). Fatal workplace injuries in Nigeria between 1987 and 1996 indicate that 71 deaths were recorded out of 3,183 reported injuries from a wide range of industrial settings, suggesting under-reporting (Ezenwa 2001). Similarly, there was colossal under-reporting of injuries and deaths in Nigeria from 2002 to 2012, as only 93 injuries and 46 deaths were reported with significant failures in penalising offenders (Umeokafor et al. 2014b). In addition, work tools, trips and falls and articulated machinery have been identified as predominant causes of accidents in south-western Nigeria (Williams et al. 2019). Thus, safety regulators in Nigeria are overwhelmed due to low manpower (CIS 2006) and poor enforcement mechanisms (Umeokafor et al. 2020). In addition, supervisory agencies in Nigeria are not effectively enforcing available safety policies due to corruption, incompetence, negative safety culture and poor training (Umeokafor 2019). Also, there are overlaps in terms of regulations, as Nigeria lacks comprehensive safety legislation unlike developed countries like Australia and United Kingdom (Animashaun and Odeku 2014; Emetumah and Okoye 2018). Regulatory deficiencies in Nigeria hamper safety management due to challenges in carrying out compliance assessment (Abubakar 2015). Hence, organisations undertaking mining operations can involve employees in policy design and implementation (Wozniak and Jurczyk 2020), thereby fostering regulatory compliance.

Factors Affecting Regulatory Compliance During Mining Activities

Several factors have been identified as affecting compliance during mining activities. Communal involvement, mining equipment and circumstances have been identified as pertinent factors militating against robust environmental compliance during mining activities in Ghana (Tuokuu et al. 2018). According to Dahl et al. (2014), safety compliance can be predicted by factors like work procedures and job criteria, among others, thus demonstrating the importance of carrying top management along in regulatory policy design. Also, work conditions and employers are factors that can predict injures linked to long work hours during mining activities in the United States (Friedman et al. 2019). Regression modelling of miners' safety experiences in Ghana shows significant prediction by factors such as mining conditions, mining tools, among others (Amponsah-Tawiah et al. 2013). In western Kenya, logistic regression analysis has been applied in predicting severe injury prevalence during small-scale mining activities where poor management, job stress and satisfactory attitude of miners were factors that fitted in the model, based on an insignificant Hosmer and Lemeshow test result (Ajith and Ghosh 2019). However, miners' single-injury incidents in Kenya were prevalent, while most miners were not confident in the ability of management to protect them from harm during mining activities (Ajith et al. 2020). In the same vein, data from South Africa suggest progressive increment in the prevalence of respiratory diseases, which raises concern for miners' wellbeing, with management of mining sites very much culpable (Nelson 2013; Sepadi et al. 2020).

Research Objectives

Despite prevalence of regulatory noncompliance, little attention has been paid to safety and environmental compliance evaluation during mining activities. Furthermore, there is paucity of information on factorial prediction of safety and environmental regulatory compliance during mining activities in Nigeria. Therefore, this research aimed at developing a potential approach for evaluating safety and environmental regulatory compliance during mining activities, using miners' prevalence rankings of safety and environmental noncompliance effects, as well as factorial prediction of miners having compliance issues.

MATERIAL AND METHODS

A cross-sectional survey was used for data collection where self-assessment questionnaires were administered to miners. The satisfaction evaluation approach used by Li et al. (2019), where residents in a Chinese mining province ranked their satisfaction with factors affecting their wellbeing on a 7-point Likert scale, was modified to suit the data needs of the present study. A section of the self-assessment questionnaire was designed such that surveyed miners indicated prevalence rankings of fifteen common safety and environmental noncompliance effects during mining activities (namely, Minor injuries, Strenuous conditions, Serious bodily harm, Air pollution, Permanent disability, Water pollution, Communal clashes, Death of miners, Soil/land degradation, Poor welfare, Vegetation loss, Wildlife loss, Negative reputation, Incompetence, and Miners' attitude), on a five-point Likert scale, which ranged from very low (1) to very high (5). In determining the fifteen noncompliance effects, pertinent facets from Parts IV and V of Nigeria's Mineral Mining Regulations of 2011 (NMMR 2011) were selected and included in the self-assessment questionnaire mainly as noun-phrases. Also, relevant factors affecting safety and environmental compliance during mining activities were included in the questionnaire, as categorical variables. Other items in the questionnaire covered having compliance issues in the last one year from the survey, use of only small hand tools, noncompliance causes, noncompliance injuries and regulatory noncompliance penalties.

The study respondents were miners engaged in open cast mining of granite, stone dust, lead, zinc and limestone in Ebonyi State. Eight mining sites were selected for data collection, based on their classification as active sites by mine regulators in the study area. The sites studied were Umuoghara (Ezza north Local Government), Ezillo (Ishielu Local Government), Ngbo (Ohaukwu Local Government), Mkwuma-akpatakpa (Izzi Local Government), Enyigba (Izzi Local Government), Ndufu-Alike (Ikwo Local Government), Amasiri (Afikpo North Local Government) and Ishiagu (Ivo Local Government). Interactions with leaders of the miners' association in Ebonyi State indicate that the mining sites selected had at least 60 miners operating in each of them. In determining the study's sample size, random sampling was used in sampling 300 miners operating within the eight mining sites studied. Prior to data collection, each mining site was visited at least twice in order to familiarise with miners as well as the vicinity of the mining site. The essence of doing this was to remove any barriers that may hinder respondents from providing data required for the study (Liamputtong 2008).

During data collection, each miner was informed about the voluntary nature of the study as well as maintenance of their anonymity. Since the survey instrument was typewritten in English, two field assistants who are familiar with local dialects of the Igbo language spoken around the mining sites aided the first author in administering the self-assessment questionnaires. All respondents who participated in the study gave full consent prior to commencement of data collection. Furthermore, the leaders of the miners' association in Ebonyi State gave permission, which was important since many miners refused to participate in the study without verbal instructions from their leaders. Data collection from the mining sites was sequential, with about one month spent on each of the eight sites studied. Out of the 300 miners surveyed, 246 valid questionnaires were retrieved for analysis.

Data Analysis

Statistical analysis for the study was done using SPSS version 21. Data collected on prevalence of fifteen noncompliance effect variables were analysed using principal component analysis (PCA), in order to ascertain their main components and structural dimensions. PCA was practicable given that the variables were in ordinal scale, their sample size is not small ($n = 246$) and there was adequate correlation between most variables within the dataset. In terms of sample adequacy, Kaiser-Meyer-Olkin (KMO)

Measure of Sampling Adequacy was used since it measures adequacy with scores ranging from 0 to 1 with a value of 0.6 or more, indicating adequacy of the sample size (Shlens 2005). Variables with standard deviation scores of greater than 3, as well as those without correlation coefficients $r \geq 0.3$, are usually removed from the PCA since they may be measuring divergent constructs. In terms of suitability for data reduction, Bartlett's test of Sphericity was applicable because it uses *p* value to calculate the level of significance where values less than 0.05 are termed as significant, indicating suitability of the dataset for PCA (Kaiser 1974). Components to be retained were determined using a combination of Eigenvalue-one Criterion (components with Eigenvalues of 1 or more are retained) (Kasier 1960), Scree plot test and structural interpretability based on Varimax rotation method. Retained components were then interpreted and discussed from the rotated component matrix, which showed their respective factor loadings.

In developing a model that can predict having safety and environmental compliance issues during mining activities, binomial logistic regression (BLR) was applicable due to its ability to predict the outcome of a binomial dependent variable (Harrell 2015). BLR can estimate logarithm of the odds (log-odds) when the independent variables are linearly combined with a dichotomous outcome, as long as certain assumptions are met, that is, one mutually exclusive dependent dichotomous variable and one or more mutually exclusive continuous/nominal variables, a sample size of more than 100, linear relationship between the dependent variable's logit and continuous independent variables (not applicable in this since continuous variables were not used), no multicollinearity between the independent variables (using dummy variables) and absence of a case-wise plot indicating that there were no outliers (Tabachnick and Fidell 2007). After trying out all the variables under safety and environmental noncompliance issues during mining activities (see Table 1), "common cause of regulatory noncompliance" and "use of only small hand tools" met the assumptions with respect to predicting the outcome variable, hence their application in the BLR. Therefore, miners' responses to the dichotomous outcome variable (compliance issues in the past one year) were predicted by common causes of noncompliance ("Host communities"; "Miners' attitude"; "Management"; "Regulators"; "Work conditions") and use of only small hand tools ("yes"; "no"). A BLR modelling a binomial variable Y with two independent variables, X_1 and X_2 will have a logit link function as follows:

$$\text{logit}(Y) = \log_b p/(1-p) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \varepsilon \quad (1)$$

Where:

b = base of the logarithm; p = probability of the success for binary response; β_0 = model intercept (constant); β_1 and β_2 = parameters of the model for X_1 and X_2 respectively; ε = errors.

RESULTS

Table 1 indicates that about fifty-four percent of miners surveyed affirmed to having had compliance issues in the past one year. Management of mining companies, government regulators and host communities were the most common causes of noncompliance, as they cumulatively covered more than seventy-five percent of responses. Falling debris/objects were identified as the most common cause of acci-

Table 1: Safety and environmental noncompliance issues during mining activities (n = 246)

	N	%
Compliance Issues In The Past One Year?		
No	112	45.5
Yes	134	54.5
Most Common Cause Of Noncompliance		
Host community	58	23.6
Miners' attitude	29	11.8
Management	75	30.5
Government regulators	70	28.5
Harsh work conditions	14	5.7
Most Common Cause Of Accidents/Injuries		
Incompetence	38	15.4
Poisonous gases	39	15.9
Falling debris/objects	115	46.7
Fire/explosion	49	19.9
Mining equipment	5	2
Most Common Noncompliance Penalty		
Caution	38	15.4
Fines	138	56.1
License suspension	53	21.5
License revocation	13	5.3
Criminal penalty	4	1.6
Use Of Only Small Hand Tools?		
Yes	196	79.7
No	50	20.3

dents/injuries as indicated by about forty-seven percent of surveyed miners. In terms of most common penalty for noncompliance, fines and license suspension were indicated by about fifty-six percent and twenty-one percent respectively of miners surveyed. Furthermore, over seventy percent of surveyed miners indicated that they use only small hand tools for mining activities.

Safety and Environmental Noncompliance Effects

In carrying out PCA for prevalence rankings of noncompliance effects, initial extraction showed that overall KMO measure of sampling adequacy for the set of variables was .740, which is acceptable for PCA. Minimum and maximum KMO measures of sampling adequacy for individual variables in the dataset were also tolerable, and they ranged from .810 to .565 as indicated in the anti-image matrices. In terms of Bartlett's test of sphericity, the outputs show statistically significant results for variables in the PCA; χ^2 (105) = 1063.643, $p < .0005$. The PCA initially extracted 5 components, which explained the variance for 64.93 percent of eigenvalues above 1. However, interpretability of rotated factor loadings suggested retaining four components. Scree plot and parallel analysis also supported the extraction of the first four components. Furthermore, one variable had to be removed from the PCA ("communal clashes") because of low correlation with other variables. Therefore, a forced extraction of four components was carried out with 60.37 percent of the variables explained, which gave the interpretable structure required as shown in the rotated component matrix (see Table 2). Prevalence rankings of safety and environmental noncompliance effects were interpreted based on a four-component structure where five variables ("death of miners", "permanent disability", "serious bodily harm", "minor injuries" and "strenuous work conditions") were strongly loaded to component 1 while five variables ("water pollution", "soil/land degradation", "vegetation loss", "wildlife loss" and "air pollution") were also strongly loaded to component 2. Furthermore, two variables ("miners' incompetence" and "poor welfare") were strongly loaded to component 3, while two variables ("miners' negative reputation" and "miners' bad attitude") were also strongly loaded to component 4.

Out of the five variables strongly loaded to component 1, "minor injuries" had the highest loading score of .821 while "death of miners" had the lowest factor loading score of .591. For component 2, "vegetation loss" had the highest factor loading score of .784 while "water pollution" had the lowest factor loading score of .602. In addition, "miners' incompetence" had a higher factor loading than the other variable ("poor welfare") under component 3. Similarly, "miners'

Table 2: Rotated component matrix for safety and environmental noncompliance effects

Variables	*Component loadings*				*Communalities*
	1	*2*	*3*	*4*	
Death of miners		0.591			0.493
Permanent disability		0.748			0.584
Serious bodily harm		0.81			0.674
Minor injuries		0.821			0.721
Strenuous work conditions		0.591			0.61
Water pollution	0.602				0.509
Soil/land degradation	0.761				0.677
Vegetation loss	0.784				0.668
Wildlife loss	0.765				0.636
Air pollution	0.606				0.38
Miners' incompetence			0.764		0.663
Poor welfare			0.722		0.554
Miners' negative reputation				0.83	0.69
Miners' bad attitude				0.724	0.594
Values less than .380 were removed					

negative reputation" had a higher factor loading score than the second variable ("miners' bad attitude") under component 4. In terms of communalities, "minor injuries" had the highest communality score (.721) while "air pollution" had the lowest communality score (.380).

Model for Measuring Safety and Environmental Compliance During Mining Activities

BLR was used to predict the outcome of miners' dichotomous responses on having compliance issues in the last one year. Independent variables used as predictors for the BLR model are common causes of regulatory noncompliance, and use of only small hand tools for mining activities. In terms of mutual exclusivity, inspection of the data set shows that the outcome and predictor variables are mutually exclusive since multiple responses were not applicable in the data collection instrument. Furthermore, sample size was adequate (*n* = 246) for BLR modelling. Linear relationship between the outcome variable and any continuous independent variables was not applicable to this model since no continuous variables were used. Nonetheless, dummy variables were created for four out of five categories of common causes of noncompliance and one of two categories of using only small hand tools for mining activities. The essence of doing this was to have dichotomous responses that can be fit into a linear regression, which was used as statistical testing for multicollinearity. Collinearity statistics for the predictor variables were all above .100 in terms of tolerance, indicating that multicollinearity was not a problem for the dataset. Furthermore, the BLR output shows that case-wise plot was not produced indicating the absence of significant outliers in the dataset.

Overall, results show that the BLR model was marginally statistically insignificant, χ^2 (5) = 10.733, p = .057 as indicated in the overall model fitting information in Table 3. However, the BLR model was not a poor fit as shown by the Hosmer and Lemeshow Test statistic, which was insignificant. Parameter estimates of the overall BLR model indicates that all the variables had decreasing log-odd coefficients (negative values for the B column), which implies that exponential odds were all less than those of their respective reference categories.

On that note, the odds of "host communities" causing miners' compliance issues in the last 1 year was .253 (95% CI, .070 to .912) times lower than that caused by "harsh work conditions" while "miners' attitude" causing miners' compliance issues in the last 1 year had odds of .378 (95% CI, .096 to 1.494) times lower than that caused by "harsh work conditions". Furthermore, the odds of "management" causing miners' compliance issues in the last 1 year was .245 (95% CI, .070 to .860) times lower than that caused by harsh work conditions while "government regulators" causing miners' compliance issues in the last 1 year had odds of .439 (95% CI, .125 to 1.542) times lower than that caused by "harsh work conditions". Similarly, the odds for "use of

Table 3: Parameter estimates for factorial prediction of having compliance during mining activities

	B	*S.E.*	*Wald*	*Df*	*Sig.*	*Exp (B)*	*95% C.I.for EXP(B)*	
							Lower	*Upper*
Common noncompliance [Harsh work conditions: reference]								
Host communities	-1.372	0.653	4.415	1	.036*	0.253	0.07	0.912
Miners' attitude	-0.973	0.701	1.925	1	0.165	0.378	0.096	1.494
Management	-1.406	0.64	4.818	1	.028*	0.245	0.07	0.86
Government regulators	-0.824	0.641	1.651	1	0.199	0.439	0.125	1.542
Use of only small hand tools [No: reference]								
Yes	-0.507	0.327	2.399	1	0.121	0.603	0.317	1.144
Constant	1.324	0.652	4.121	1	0.042	3.758		

Overall model fitness: Chi-square = 10.733, df = 5, p-value = .057
Hosmer and Lemeshow Test: Chi-square = 3.257, df = 5, p-value = .660
* = significant (p < 0.05)

only small hand tools" causing miners' compliance issues in the last 1 year was .603 (95% CI, .317 to 1.144) times lower than that caused by not using only small hand tools. From Table 4, two out of the five categories of independent variables significantly predicted the likelihood of miners having safety and environmental compliance issues in the last 2 years, that is, "host communities" (Wald χ^2 (4) = 4.415, p = .036) and "management" (Wald χ^2 (1) = 4.818, p = .028).

DISCUSSION

Miners' safety and environmental compliance issues (see Table 1) show that fines were identified as the most common noncompliance penalty by more than half of surveyed miners, indicating that regulators may be more interest in revenue generation as opposed to other measures of noncompliance monitoring. In addition, over seventy percent of miners surveyed acknowledged to using only small hand tools, which shows high prevalence of artisanal mining activities with precarious safety and environmental consequences (Ajith et al. 2020).

Principal components of safety and environmental regulatory noncompliance effects, as well as their dimensions are illustrated in Figure 1. The PCA had a four-component structure where the five variables (Death of miners, Permanent disability, Serious bodily harm, Minor injuries and Strenuous work conditions) under the first component are all pertaining towards the "human" effects of safety and environmental noncompliance. The human factor is attributable to the dysfunction in safety regulatory enforcement in Nigeria (Umeokafor 2019; Umeokafor et al. 2014a), which hampers compliance with safety and environmental directives (Animashaun and Odeku 2014; Umeokafor et al. 2014a,b; Abubakar 2015; Emetumah and Okoye 2018). The second component also had five variables (Water pollution, Soil/land degradation, Vegetation loss, Wildlife loss and Air pollution) under it and these variables are all pertaining towards "environmental" effects of regulatory noncompliance. These noncompliance effect variables can be described as environmental because their features comprise of physical and biological components of the environmental system, from

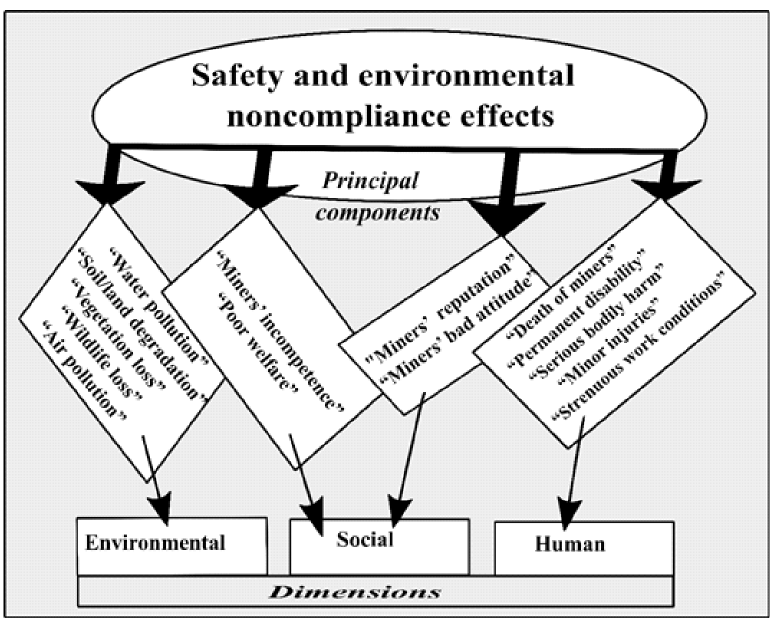

Fig. 1. Principal components and dimensions of safety and environmental noncompliance effects during mining activities
Source: Authors

which minable mineral resources emanate from. These environmental factors can be exacerbated by not carrying host communities along in policy design (Tuokuu et al. 2018; Wozniak and Jurczyk 2020). Therefore, variables under the second component demonstrate the importance of striking a balance in sustainability dimensions (Endl et al. 2019). The third and fourth components had two under each of them (third component: Miners' incompetence and Poor welfare; fourth component: Miners' negative reputation and Miners' bad attitude), and all four variables are seemly related to "social" effects of safety and environmental regulatory noncompliance because these variables are mostly based on interactions between miners and stakeholders. These variables of social effects under the third and fourth components are in line with the social dimension of sustainable development (Alves et al. 2020). This position also demonstrates the essence of balancing the social dimension with other sustainability dimensions.

The results of the BLR for measuring safety and environmental compliance indicate that the model was not a poor fit (Hosmer and Lemeshow Test = .660), and this is similar to the logistic regression carried out by Ajith and Ghosh (2019), which was a good-fit in terms of predicting severe injury prevalence during mining activities in Western Kenya. Furthermore, BLR results show that all the exponential odds for categories of the independent variables were less than their respective reference categories (see Table 3). This position was also corroborated by the BLR's significance level, which was very close to the alpha level, as shown in the model fitting information. Even though the BLR model was marginally insignificant (overall model fitness = .057), the findings align with its aim of determining the viability of predicting noncompliance based on the factors in the model. Since the study was not looking at precision of the factorial predictors, the BLR model is viable given that it was not a poor fit.

Figure 2 illustrates the factorial predictors used in the BLR model. "Government regulators" are pertinent to compliance during mining activities, since they determine and enforce policy framework required to maintain safety and environmental efficacy. However, policy design and enforcement depend on having adequate regulatory manpower, which may be inadequate in Nigeria (CIS 2006; Umeokafor et al. 2020). From the BLR, "host communities" and "management"

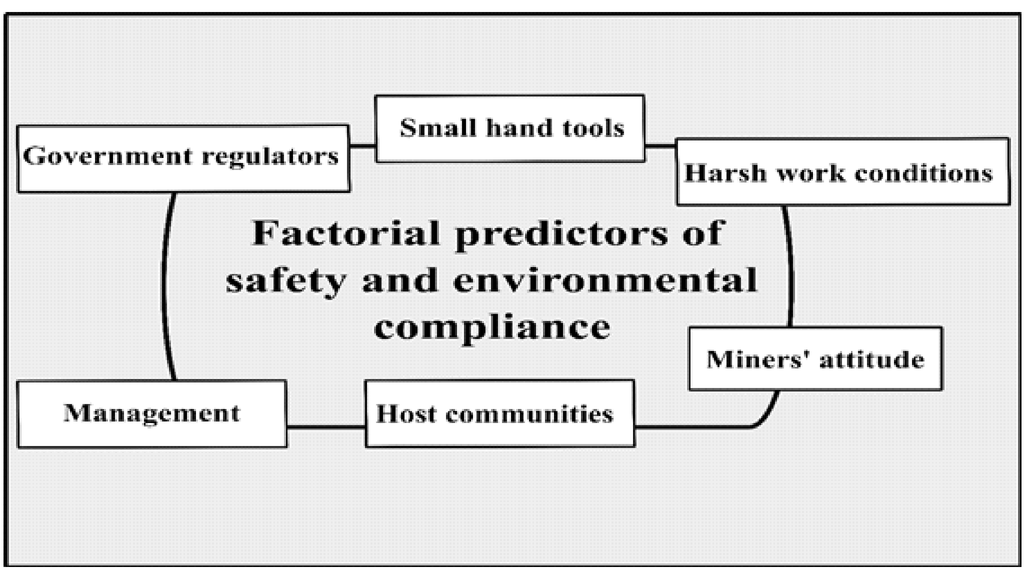

Fig. 2. Factorial predictors of safety and environmental compliance during mining activities
Source: Authors

were significant in terms of predicting having safety and environmental compliance issues during mining activities. Incidentally, managements of mining companies were also blameworthy in the prevalence of respiratory diseases in South Africa, based on logistic regression modelling (Nelson 2013; Sepadi et al. 2020). Similarly, employers have also been linked to the prevalence of injuries among miners in the United States (Friedman et al. 2019). In addition, "use of only small hand tools" (which may be classed as artisanal) having the highest odds out of the six categorical variables examined, may be attributed to the type of injuries miners experienced while undertaking mining activities (Ajith et al. 2020). Furthermore, the significant variables in the BLR ("host communities" and "management") can be described as being intrinsic aspects of the mining process because they are fundamental to managing mining activities. This is in line with the findings of Dahl et al. (2014) on the importance of involving all relevant stakeholders in the safety process, thereby increasing compliance during mining activities. None of the variables in the logistic model had odds higher than the reference variable of "Harsh work conditions". Amponsah-Tawiah et al. (2013) in modelling Ghanaian miners' safety experiences also identified the importance of mining conditions for effective management of hazards from mining activities.

The proposed approach for assessing safety and environmental regulatory compliance during mining activities is illustrated in Figure 3. Due to their level of significance in the BLR model, host communities and management should be given special attention because of the role they play in fostering compliance during mining activities. Mining tools also affect the environmental dimension of noncompliance effects because mining activities take place on the earth crust, which is an important environmental resource (Samatemba et al. 2020). Work conditions depend on the measures taken to

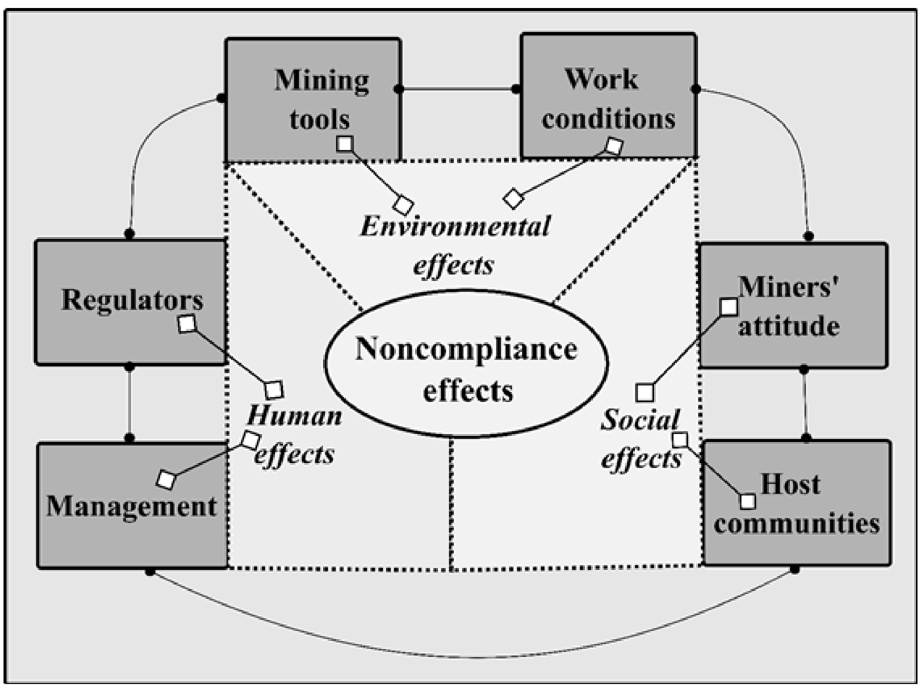

Fig. 3. Illustration of the proposed approach for assessing safety and environmental compliance during mining activities
Source: Authors

provide an environmentally conducive atmosphere for undertaking mining activities. Miners' attitude, which follows the social dimension of safety and environmental noncompliance effects, looks at the collective tendency of miners to comply with laid down safety and environmental guidelines during mining activities. This implies that miners may not necessarily follow guidelines due to their personal attitudes (Sepadi et al. 2020). Host communities also follow the social dimension since they are vital custodians of societal values around mining sites. Regulators are also important to the whole arrangement since their ability to effectively enforce and monitor safety and environmental compliance, goes a long way in maintaining harmony (Umeokafor et al. 2020). Management in mining companies are responsible for directing activities of miners as well as providing conducive surroundings, thus nurturing safety and well-being during mining activities (Friedman et al. 2019).

CONCLUSION

The study provides a sustainable approach for assessing environmental and safety regulatory compliance during mining activities, using principal component analysis and model prediction. The principal components of environmental and safety regulatory compliance during mining activities were determined to follow environmental, social and human dimensions. The proposed approach uses the six factorial predictors ("work conditions", "regulators", "miners' attitude", "mining tools", "management" and "host communities") from the BLR model and the three dimensions ("environmental", "human" and "social") from the PCA of safety and environmental noncompliance effects. The proposed approach may be useful in increasing safety and environmental regulatory compliance during mining activities.

RECOMMENDATIONS

The study has provided a sustainable approach for assessing safety and environmental regulatory compliance during mining activities. Based on the approach, the study advocates that top management in mining companies should expand their procedural techniques by incorporating management system standards into their operational procedures, thereby increasing safety and environmental compliance during mining activities. Also, miners and host communities should be adequately involved in designing regulatory mechanisms affecting mining activities. Furthermore, a comprehensive study aimed at evaluating safety and environmental compliance during mining activities in a large mining company is also suggested in order to test the approach developed in this study.

ACKNOWLEDGEMENT

Special thanks goes out to all miners who participated in the study. This work was partly supported by Tertiary Education Trust Fund (TETFUND), a local PhD grant.

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Paper received for publication in July, 2020
Paper accepted for publication in October, 2020