The Environmental Impact of Mining Activities in the Local Community: A Structural Equation Modelling Approach

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Abstract

This study investigates the impact of mining activity on the environment of a local mining community. A novel approach was employed by contextualizing the role of deforestation and operational disturbance of mining activities in dragging environmental sustainability of the local community. This was anchored by specifying and estimating a structural equation model (SEM). Data used for the analysis were collected by administering questionnaires among 200 residents and indigenes of Ibise-Komu community in Oyo State, Nigeria. The instrument administration was facilitated by two indigenous volunteers who introduced the researcher to the community leaders who in turn mobilized the general community to participate in the study. The choice of this community was informed by the narratives of the locals that their environment has been perennially destroyed by the mining companies. The findings revealed that deforestation and operational disturbance are characteristic of the mining companies in the community, which have done little to champion the development of their host environment. As a result, the community environment is littered with land, water and air pollution which is majorly induced by indiscriminate mining of mineral deposits in the community. It is therefore recommended that the government and regulatory agencies should tie the operational license of the mining companies to their continuous compliance with environmental safety and sustainability of their host communities. This is a mechanism of managing conflicts between the community and the mines.

Keywords: Environment, mining activity, pollution, structural equation modelling, Nigeria

1. Introduction

The mining activity has been connected with an array of environmental consequences. For example, Haddaway et al. (2019) claimed that mining is a driver of the climate change that has been ravaging the world. The mechanism of the environmental impact of mining was particularly argued by Naibbi and Chindo (2020), Obasi et al. (2021) and Idowu (2022). The initial process of mining involves a disruption of the ecosystem with environmental-depleting practices such as deforestation, bush burning, habitat displacement and loss of biodiversity (Naibbi and Chindo, 2020). In addition, during the actual mining process, the mines are predisposed to cause disturbance to healthy living among the residents of their host communities (Idowu, 2022). They also inadvertently release greenhouse gases and emissions which result in increased temperature and reduced living conditions (Obasi et al., 2021). This subjects the locals to untoward environmental hazards, constituting a drag on their health trajectories (Idowu, 2022). These streams of environmental impact of mining have made researchers call for formidable government regulation and supervision of mining activities in any mineral-rich locality (Ogunleye et al., 2022; Aliu et al., 2022).

This paper intends to re-establish the evidence of environmental impact of mining in Ibise-Komu (a host community of mines) in Itesiwaju Local Government Area of Oyo State, Nigeria. The motivation for the present research is related to the personal experience of the author. Prior to the decision to conduct the research, the author visited the study area and noticed unusual hot temperature within the area. The roads of Ibise-Komu were also at deplorable state while many roofs in the community had become eyesore, suggesting poor living conditions of the inhabitants. A casual interview with some locals indicated that the presence of mining companies in Ibise-Komu had reversed the impressive relationship between the community and its environment. There was unanimous response that mining activity had degraded the Ibise-Komu community. However, this anecdotal evidence was insufficient to form a narrative of the environmental impact of mining in Ibise-Komu. Thus, the present research was put together to better understand the role of mining on the stance of environmental sustainability of Ibise-Komu community in Oyo State, Nigeria.

Following these introductory paragraphs, the reminder of the paper is organized into four sections. Section 2 takes a brief tour of the related literature, Section 3 discusses the methodology adopted in the study, including the model specification, estimation and the sampling procedure. Section 4 reports the empirical results and discusses the emerging findings. Finally, Section 5 concludes the study and offers recommendations towards improving the environmental conditions of the study area.

2. A Tour of the Related Literature

Ogbonna et al. (2015) conducted an environmental assessment of coal mining in Akwuke and Iva mine communities in Enugu, Nigeria. The authors were interested in collating and analysing views of locals in the selected communities regarding the impact of coal mining on their health, means of livelihood and environment. A semi-structured questionnaire was designed by the authors. This was combined with personal observation to aid the data collection process. As reported by the respondents, the authors found that some trees and animals had gone extinct due to intensive coal mining in the host communities. In addition, many members of the communities had faced serious health hazards including blindness, cancer and heart diseases. Most importantly, the mining process has made the roads of the host communities degraded with incessant land pollution which had remained unabated. In their conclusive remarks, Ogbonna et al. (2015) argued that coal mining has been a major source of burden, rather than gain, for the environment of the sampled communities.

Similarly, Adeoye (2016) assessed the effect of gold mining on land degradation in gold-rich communities of Ijesaland, Osun state, Nigeria. Spatial data on the patterns of land use were collected and analysed relative to the occurrence of land degradation in thirty-seven mining sites in ten mining communities. To include the perspectives of the locals, focus group discussions were conducted among 500 adult men and women in the visited communities. The opinions of the participants suggested that the mining activities have caused mixed impact in their communities. On the one hand, mining was linked with improved socio-economic status of the residents of the communities. This was described as positive spill-over impact of the mining activity. On the other hand, the respondents declared that mining was the harbinger of the major adverse effects they have experienced on their environment. In particular, where the mines are not closely monitored by the government authorities, they tend to predispose their host communities to unpleasant land pollution and other environmental hazards (Adeoye, 2016).

Omotehinse and Ako (2019) investigated the environmental impact of mineral exploration in Nigeria. The researchers were particular about the effects of tin and coal exploration in Jos and Enugu, respectively. Data were collected using a mixed approach including field survey, documentary analysis, direct mapping and observations. Findings indicated that the environment of the selected locations have been degraded by contaminants generated during the mining processes. This had threatened the ecosystem within the host communities as the authors observed that their vegetation has been rendered unusable for nutritional and health purposes. These environmental consequences have persistently taken new forms because the compliance of the mining companies with the mining laws is very limited, making their environmental behaviours unchecked (Omotehinde and Ako, 2019). Similar findings were further confirmed by Adesipo et al. (2020) in their analysis of the relationship between floristic composition and mining activity. In specific terms, Adesipo et al. (2020) stated that deforestation and exposure of the forest soils to direct sunlight have greatly stressed the environmental balance of the mining communities.

In a comparable study which was analysed using the remote sensing approach, Oluwafemi et al. (2021) showed that artisanal mining could cause land and vegetation degradation which might consequently result in loss of biodiversity, habitat displacement and ecological modification. Having collected time series data on vegetation, land use and biomass, the authors applied the GIS-based Normalized Differential Vegetation Index (NDVI) to analyse the space-based data ranging from 1972 to 2011. The results of the data analysis hinted that the NDVI values of the input data were in excess of their upper bands but within their lower bands. It therefore follows that mining activity represents push and pull factors to economic prosperity and environmental sustainability of the communities (Oluwafemi et al., 2021). Earlier, a GIS-focused research by Atejioye and Odeyemi (2018) linked sand mining in Ekiti State, Nigeria to indiscriminate pollution of land and water resources in the State. Also, in a review of environmental health situation of Nigeria, Pona et al. (2021) partly attributed the blame of poor environmental standards in Nigeria to the extractive industry in general and mining companies in particular.

Given the lead poisoning outbreak in Zamfara, Nigeria in 2010, Bartrem et al. (2022) investigated the vulnerabilities and complexities of challenges faced by gold mining villages in Zamfara. The authors also examined the issues of climate change within the villages and the scenarios of incessant infighting among the residents of the villages. The methodology of the research was anchored by a meta-analysis of the literature where peer-reviewed articles that have been published on the subject matter were systematically reviewed and the emerging insights from them were pieced together. Findings pointed that, since the incidence of lead poisoning, there have been healthy environmental practices by mining companies in the Zamfara communities. This has been facilitated by the environmental and mineral management policies that the government has pursued towards improving environmental sustainability of mining activity (Bartrem et al., 2022).

Most recently, Adewumi and Laniyan (2023) examined the level of environmental pollution, ecological hazards, and health risks related to the presence of metals in the water, which might be occasioned by mining activities in Pb-Zn-F mining area, North-eastern Nigeria. The authors analysed the levels of heavy metals in 36 water samples which were drawn from the surface and mines. It was found that other than Cu, Zn, As, Cd, Sb, and Cd (surface water, dry season), which were below the acceptable norms, all water samples had metals over the suggested limits. Besides, the ecological risk assessments were conducted with the result that heavy metals in waters used by the locals have posed serious threats to their living and health trajectories. In particular, both adults and children in the region were susceptible to carcinogenic and non-carcinogenic health hazards since the hazard index values for both indices were above the upper bands. Thus, there was high incidence of water pollution in the mining area (Adewumi and Laniyan, 2023).

3. Methods

The analytical approach in this study takes insights from the structural equation modelling (SEM). The use of SEM is related with the presumption that environmental pollution is popularly indirectly measured by land pollution, water pollution and air pollution. Hence, environmental pollution is considered in this study as a latent variable while its three forms are observed variables. Also, mining activity involves technical processes which are best understood by the miners. Rather, this study takes deforestation and operational disturbance as the observable by-products of the mining activity. To this end, the observed variables are applied to proxy the latent variables as the cross impact among them is examined. We begin the SEM framework by stating the structural model as in equation (1):

$$\text{ENVIMP} = \beta\text{MINACT} + \text{e} \ldots \ldots \quad (1)$$

Where ENVIMP is the environmental impact, MINACT is the mining activity, β is the parameter measuring the impact of mining activity on the environment and e is the stochastic error term which is distributed with zero mean and constant variance. Following this, the measurement model, which contains the relationships between the latent and observed exogenous variables is constructed in equation (2) where y_1 is deforestation, y_2 is operational disturbance, q is the mining activity, β_1 and β_2 are measurement parameters, and e_1 and e_2 are measurement error terms for the exogenous variables. While y_1 and y_2 are exogenous observed variables, q is exogenous latent variable.

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} \beta_1 & 0 \\ \beta_2 & 0 \end{bmatrix} [q] + \begin{bmatrix} e_1 \\ e_2 \end{bmatrix} \ldots \ldots \quad (2)$$

The measurement model for the endogenous variables is contained in equation (3) where x_1 is land pollution, x_2 is water pollution and x_3 is air pollution. p is the latent endogenous variable (environmental impact), α_1, α_2 and α_3 are measurement parameters for the endogenous variable (p) while v_1, v_2 and v_3 are measurement error terms. Finally, the factor loadings from exogenous observed variables to endogenous observed variables are captured in equation (4) where all the variables retain their earlier descriptions, the π's are the factor loadings and the u's are the error terms. The focus of the present study is to estimate the π's. Having estimated the factor loadings, the coefficient estimates were interpreted in percentage terms and the inferences were explained using 5% and 10% as the levels of statistical significance.

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} \alpha_1 & 0 \\ \alpha_2 & 0 \\ \alpha_3 & 0 \end{bmatrix} [p] + \begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix} \ldots \ldots \quad (3)$$

$$\begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} \pi_1 & \pi_2 \\ \pi_3 & \pi_4 \\ \pi_5 & \pi_6 \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \end{bmatrix} + \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix} \ldots \ldots \quad (4)$$

Information on the observed variables was obtained by administering questionnaires among 200 residents of Ibise-Komu community in Itesiwaju Local Government Area of Oyo State, Nigeria. The residents were randomly selected using a simple random sampling technique. The questionnaires surveyed the perceptions of the residents on the existence or otherwise of deforestation and operational disturbance (proxies for side-effects of mining activity) and the occurrence of the three forms of environmental pollution (land, water and air). The instrument administration was facilitated by engagement of two locals as gatekeepers in the present study. The gatekeepers voluntarily participated to make the researcher familiar with the community and its residents. After the instrument administration, the obtained qualitative responses were converted into quantitative terms using the codes ascribed to the instruments. Then, the data were exported to and analyzed in the Stata software.

4. **Empirical Results and Discussion of Findings**

We begin the SEM analysis by estimating the covariances of the sets of latent and observed variables. This is presented in Table 1 where it is shown that there are strong associations among the variables. This justifies the preliminary decision of bringing the variables together. In particular, deforestation is largely correlated with operational disturbance, suggesting that the two variables move in the same direction. That is, a deforestation attempt inadvertently displaces human habitation and contributes to uncomfortable living. Furthermore, land pollution co-moves with the other forms of pollution. This may be explained by the practice that where soil erosion results from land pollution, the water in the environment is polluted. The mining operation also generates metal residues which pollute drinkable water in the community. Similarly, the mining companies use heavy trucks to transport their materials and inputs as well as their output. The exhausts from the trucks pollute air in the environment, as harmful gases are emitted into the atmosphere. In addition, the mining trucks deplete the roads because they are heavier than the carrying capacity of the roads.

Table 1: Estimated covariances among the variables

	DEFORE	OPEDIS	LANPOL	WATPOL	AIRPOL
DEFORE	4.32				
OPEDIS	3.55	3.58			
LANPOL	2.28	2.57	3.21		
WATPOL	3.04	2.41	3.36	2.99	
AIRPOL	3.10	2.58	3.49	2.50	3.43

Where DEFORE – deforestation; OPEDIS – operational disturbance; LANPOL – land pollution; WATPOL – water pollution; and AIRPOL – air pollution.

Next, the estimates of path coefficients for the variables were estimated. The path coefficients measure the changes in the latent variables that are accounted for by the observed variables. Table 2 demonstrates that deforestation shares about 39% in the variation of side-effects of mining activity while operational disturbance shares 28%. This finding suggests that deforestation and operational disturbance (with joint contribution of 67%) are natural consequences of mining activity within the sampled community. Furthermore, it was found that land pollution, water pollution and air pollution are responsible for 33%, 24% and 21% in the environmental pollution in the visited community. These pollution sources are induced by the presence of mining companies in the community. It is noteworthy that these path coefficients are all statistically significant at 5%, except air pollution whose coefficient is significant at 10%. In addition, the joint contributions of the observed variables on the latent variables are less than 100%, because there might be other drivers of the latent variables which the present study does not include. The factor loadings were then estimated. The estimates of path coefficients represented by the factor loadings show the changes in the endogenous observed variables that are determined by exogenous observed variables. This is summarized in Table 3. It was revealed that deforestation accounts for 26% in land pollution, 32% in water pollution and 19% in air pollution. On the other hand, operational disturbance is responsible for 37% in land pollution, 31% in water pollution and 29% in air pollution.

Table 2. Estimates of path coefficients running from observed variables to latent variables

Flow of relationship	Path coefficient	T-statistic
DEFORE → MINACT	0.3873	6.3387*
OPEDIS → MINACT	0.2843	4.1810*
LANPOL → ENVIMP	0.3329	4.6377*
WATPOL → ENVIMP	0.2376	2.2872*
AIRPOL → ENVIMP	0.2104	1.9862**

→ shows the relationship direction; * shows the relationship is statistically significant at 5%; ** shows the relationship is statistically significant at 10%

Table 3. Factor loadings running from exogenous variables to endogenous variables

Flow of relationship	Path coefficient	T-statistic
DEFORE → LANPOL	0.2644	5.2509*
DEFORE → WATPOL	0.3209	4.7701*
DEFORE → AIRPOL	0.1927	2.8713*
OPEDIS → LANPOL	0.3726	1.8702**
OPEDIS → WATPOL	0.3135	1.9822**
OPEDIS → AIRPOL	0.2940	3.4477*

→ shows the relationship direction; * shows the relationship is statistically significant at 5%; ** shows the relationship is statistically significant at 10%

It therefore follows that mining activities are indeed related with the scenarios of environmental pollution experienced by the host community. More particularly, the deforestation that precedes mining activity leads to destruction of soil, giving rise to soil erosion. And where the corporate social responsibility is lagging, the mining companies do not repair the roads they have destroyed. This culminates into land degradation in the community. Also, the mining operation involves practices and systems which generate acidity and contamination of the surface and ground water. This makes the available water unwholesome for daily consumption for the inhabitants. Mining operation can also result in coal fires which can generate fly ashes, toxic chemicals and greenhouse gases. These practices might result in acid rain, leading to corrugated roofs in the community. For example, the residents of Ibise-Komu community decry their persistent inhaling of harmful gases and substances in the environment.

5. Conclusions

This paper has established deforestation and operational disturbance as the side-effects of mining activity, which has negatively affected the environment of the host community where the mining company is located. It was shown that the mining company inadvertently disturbs the ecosystem in the community by clearing away important flora and fauna that have hitherto been important for community development. In addition, during the operation of mining activity, community disturbance is generated, exposing the locals to unhealthy substances, gases and emissions. More importantly, both by-products of mining activity drag environmental sustainability such that there is perennial incidences of land, water and air pollution in the community. By implication, the recurring conflicts between Ibise-Komu and the mining companies are sourced from the environmental degradation caused by the latter. It is therefore recommended that policymakers should revisit the enabling laws and regulations governing the establishment and operation of mining companies in Nigeria. In particular, the sustainability of the community environment should be the guiding framework of all mines. Also, mining companies should implement robust corporate social responsibility towards compensating the community for allowing the mining business to take place. These are mechanisms of managing conflicts between the community and the mines.

6. Limitations of the study

The variables used in this study (independent and dependent variables) were measured qualitatively through the opinions of the respondents. It is noted that quantitative measures of these variables would offer a more representation of the reality. However it is beyond the scope of this study to use scientific tools to measure deforestation and operational disturbance from mining activities or environmental tools to measure land, water and air pollution. On this basis, findings in this study are limited to the perspectives of residents in the study area. In addition, the respondents were unanimous to report that their environment has been destroyed by activities of the mining companies – this was indicated by high degrees of pollution in their community. Nevertheless, while the pollution could not be solely sourced from mining activities, the respondents did not give account of other possible causes of pollution in their environment. It follows that future researchers might wish to separate the pollution from mining activities from pollution from other economic activities in the community. We may as well have researchers who are willing to investigate the extent of compliance of the community itself with the available environmental laws and practices. Thus, the present study is limited in the interpretation of pollution measures that were analyzed. Furthermore, during the instrument administration, it was observed that some respondents were disposed to expressing their feelings and emotions beyond the options included on the administered questionnaires. Although interview sessions would be more suitable to capture the respondents' emotional expressions, such approach is not complementary with the use of SEM which was implemented in this study. As a result, this study is limited in that it does not capture the moods of the respondents. Future researchers may then be interested in conducting interview sessions among the respondents. However, another methodological approach (different from SEM) had to be employed by such researchers.

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