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Original Research Article

Statistical Analysis of Artisanal Mining Practices and Occupational Health Risks in Anka Local Government Area, Zamfara State, Nigeria

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ABSTRACT
Artisanal and small-scale mining (ASM) is a major livelihood activity in Anka Local Government Area (LGA), Zamfara State, Nigeria, but it poses significant occupational health risks. This study aimed to assess artisanal mining practices and determine their association with respiratory and musculoskeletal health outcomes among miners in Anka LGA. A cross-sectional design was employed involving 120 artisanal miners using structured questionnaires and observational assessments. Most respondents were male (90.0%) and aged 18–45 years (86.7%), with over two-thirds having at least two years of mining experience. Mining activities were predominantly dust-intensive, particularly crushing and grinding (44.2%), while personal protective equipment (PPE) use was generally low, with 52.5% reporting no PPE use. Respiratory symptoms were reported by 55.8% of miners, with chronic cough (48.3%) and wheezing (38.3%) being the most common. Musculoskeletal complaints were reported by 65.0% of respondents, with back pain (60.0%) and joint pain (53.3%) predominating. Bivariate and multivariable logistic regression analyses identified key occupational risk factors. Working more than eight hours per day, engagement in crushing and grinding activities, heavy manual lifting, and non-use of PPE significantly increased the odds of respiratory and musculoskeletal symptoms ($p < 0.05$). Model diagnostics indicated good fit, with Hosmer–Lemeshow p-values of 0.634 and 0.709 for the respiratory and musculoskeletal models, respectively, and no evidence of multicollinearity. The findings highlight the need for interventions promoting PPE use, regulating working hours, mechanizing dust-intensive tasks, and providing ergonomic training to reduce occupational health risks among artisanal miners.

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INTRODUCTION

Artisanal and small-scale mining (ASM) is a major source of income for millions of people in many African nations, including Nigeria (add citation). Despite its economic significance, ASM is linked to significant occupational and environmental health risks. Artisanal gold mining, in particular, has been closely associated with severe lead poisoning especially among children and widespread environmental contamination in Zamfara State, northern Nigeria. According to recent research, miners who processed gold ore and extracted lead were exposed to airborne lead concentrations that were up to 32 times

higher than those recorded in the US, significantly exceeding both the permissible exposure limits set by the Occupational Safety and Health Administration (OSHA) and international safety standards (Nota *et al.,* 2025). In impacted communities, elevated blood lead levels continue to represent a persistent public health concern. For example, a survey found that blood lead levels ≥10 µg/dL were present in over one-third of children aged ≤5 years from households involved in ore processing, a prevalence far higher than that observed in non-processing areas (Dooyema *et al.,* 2012). Additionally, years after the first remediation efforts, follow-up environmental assessments in affected villages continue to detect lead contamination in soil and water, suggesting ongoing exposure pathways within mining communities (Kwasi *et al.,* 2024).

Within artisanal mining environments, airborne exposure to hazardous metals remains a significant occupational risk. Respirable dust and heavy metals, such as arsenic and mercury, have been found at concentrations above WHO and US-EPA recommended limits, placing both adults and children at risk of acute and long-term health effects (Semiono *et al.,* 2023).

Beyond toxicological exposure, several studies have documented the burden of occupational health outcomes among artisanal miners, particularly respiratory and musculoskeletal disorders. Respiratory conditions such as chronic cough, wheezing, and chest tightness have been widely reported among miners exposed to dust-intensive activities like crushing and grinding. Similarly, musculoskeletal problems, including back pain, joint pain, and muscle strain, are frequently associated with prolonged working hours, heavy manual labor, and poor ergonomic conditions in ASM settings across sub-Saharan Africa. These health outcomes are often compounded by limited use of personal protective equipment (PPE) and lack of mechanization, highlighting the need for studies that directly assess the relationship between mining practices and these specific health effects.

Occupational health risks associated with artisanal mining vary across mining types and geographical locations. In Nigeria, artisanal barite mining has been linked to elevated levels of lead, barium, zinc, copper, and iron contamination in water and soil, a situation exacerbated by low awareness of safety procedures and weak regulatory enforcement, thereby increasing miners' vulnerability to chronic illnesses (Afolayan *et al.,* 2021). Similarly, a One Health evaluation of artisanal and informal mining in Benue State revealed systemic health effects, including elevated blood inflammatory markers, particularly among women, older adults, and residents living close to mining sites (Paul *et al.,* 2024). These findings highlight the complex interactions between environmental pollution, mining practices, and human health, emphasizing the importance of localized assessments of occupational hazards. Beyond Nigeria, risks associated with informal mining are widespread across Africa. A continent-wide survey reported exposure to harmful substances such as mercury, lead, arsenic, cadmium, chromium, and silica-containing dust, affecting an estimated nine million workers and their surrounding communities (Ondayo *et al.,* 2023). Despite growing awareness of these hazards, existing research remains fragmented, with limited coordination among environmental monitoring, toxicological studies, and public health assessments. Globally, the largely unregulated nature of informal mining is frequently cited as a key driver of persistent occupational health and safety challenges, contributing to frequent accidents, injuries, and chemical exposures (Hilson, 2025; Tsang *et al.,* 2020). Children are particularly vulnerable in communities where artisanal mining occurs. Evidence suggests that millions of children worldwide are involved in small-scale gold mining, exposing them to numerous risks, including toxic metal exposure, infectious diseases, malnutrition, extreme heat, and serious injuries (Allan-Blitz *et al.,* 2021). In Zamfara State, the consumption of staple foods contaminated with lead remains a major contributor to elevated blood lead levels in children. This underscores how multiple exposure pathways such as air, soil, and food interact to exacerbate adverse health outcomes (Nota *et al.,* 2025).

Overall, existing studies consistently demonstrate that small-scale mining poses multiple risks to both miners and surrounding communities, including chemical exposure, physical hazards, and social or behavioral challenges. However, there remains a notable gap in applied research that directly links specific mining practices to self-reported respiratory and musculoskeletal health outcomes at the local level using field-based survey data. In Anka Local Government Area (LGA) of Zamfara State, where artisanal mining is widespread, limited information exists regarding miners' actual practices, exposure conditions, and the statistical relationships between these practices and health outcomes measured through questionnaires and observational assessments. Addressing this gap is essential for developing effective, evidence-based interventions, strengthening occupational safety measures, and designing public health strategies tailored to the needs of small-scale miners in this area.

Therefore, this study aims to describe the prevailing artisanal mining practices in Anka LGA, identify associated occupational health risks, and determine the statistical relationships between mining practices and respiratory and musculoskeletal health outcomes. By integrating occupational and epidemiological perspectives, this research provides a localized empirical assessment intended to inform policy development and improve occupational health within artisanal mining communities.

MATERIALS AND METHODS

The study was conducted within Anka Local Government Area (LGA), Zamfara State, Nigeria. The area covers approximately 2,746 km^2 with an estimated population of 142,280, predominantly Hausa and Fulani ethnic groups. Artisanal mining is widely practiced in communities such as Bagega, Dareta, Abare, and Yar Galma, where it serves as a major source of livelihood. The region is characterized by an arid climate and high atmospheric dust levels, which contribute significantly to occupational health risks among miners.

Figure 1: Map of Anka LGA showing major artisanal mining sites

A cross-sectional study design was employed. A total of 120 artisanal miners were recruited using a multistage convenience sampling technique. The sample size was determined based on feasibility and the requirement for logistic regression analysis, following the rule of at least 10 outcome events per independent variable. Given two primary health outcomes and six key predictors, the sample size was considered adequate for stable model estimation.

Data were collected using a structured questionnaire and an observational checklist. The questionnaire was adapted from previously validated occupational health survey tools and modified to suit the artisanal mining context. It was pre-tested in a nearby mining community, and necessary refinements were made to improve clarity, reliability, and validity. The instrument collected information on socio-demographic characteristics (age, sex, education level, and mining experience), mining practices, working hours, personal protective equipment (PPE) use, and self-reported occupational health symptoms.

Observational assessments were conducted by trained research assistants using a standardized checklist, which captured workplace conditions including dust exposure levels, ventilation status, proximity to crushing and grinding activities, tools used, and chemical handling practices. Inter-observer consistency was ensured through training and supervision.

Respiratory symptoms were defined as the presence of at least one of the following self-reported conditions within the past 12 months: chronic cough, wheezing, or chest tightness. Musculoskeletal symptoms were defined as self-reported pain or discomfort in the back, joints, or muscles lasting at least one week within the past 12 months, adapted from the Nordic Musculoskeletal Questionnaire framework. Heavy manual lifting was defined as routine lifting of materials estimated to exceed 20 kg, or repeated lifting of ore and mining materials for more than 2 hours per workday, in line with occupational safety guidelines.

Ethical approval for the study was obtained from the relevant institutional ethics review committee. Written informed consent was obtained from all participants prior to data collection. Participation was voluntary, and confidentiality and anonymity of respondents were strictly maintained throughout the study.

Data were analyzed using Minitab software. Descriptive statistics such as frequencies, percentages, means, and standard deviations were used to summarize the data. Associations between categorical variables and health outcomes were assessed using Chi-square or Fisher's exact tests, with degrees of freedom reported where appropriate. Multivariable logistic regression models were used to identify predictors of respiratory and musculoskeletal outcomes. All variables considered theoretically and statistically relevant (age, sex, education, mining experience, working hours, PPE use, crushing/grinding activities, and heavy manual lifting) were included as independent variables. Adjusted odds ratios (AORs) with 95% confidence intervals were reported.

Model adequacy was assessed using Hosmer–Lemeshow goodness-of-fit tests and variance inflation factor (VIF) analysis to detect multicollinearity. Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

Characteristics of Respondents and Mining Practices

The study sample comprised 120 artisanal miners. The majority of participants were male (90.0%), with most (86.7%) falling within the 18–45-year age bracket. Approximately two-thirds (68.3%) possessed at least two years of mining experience, while 77.5% had attained no more than a primary education. Furthermore, a substantial proportion of miners (71.7%) reported working more than eight hours per day. The most common mining activity was crushing and grinding (44.2%), followed by excavation/digging (25.8%), ore washing/processing (17.5%), and transportation/haulage (12.5%). Personal protective equipment (PPE) utilization was generally low, with 52.5% reporting no use, 29.2% reporting occasional or partial use, and only 18.3% reporting regular use of PPE.

Table 1: Socio-Demographic Characteristics and Mining Practices of Respondents (N = 120)

Variable	Category	n (%)
Sex	Male	108 (90.0)
	Female	12 (10.0)
Age group (years)	18–25	28 (23.3)
	26–35	44 (36.7)
	36–45	32 (26.7)
	>45	16 (13.3)
Education	No formal	52 (43.3)
	Primary	41 (34.2)
	Secondary and above	27 (22.5)
Mining experience	<2 years	38 (31.7)
	≥2 years	82 (68.3)
Working hours/day	≤8 hours	34 (28.3)
	>8 hours	86 (71.7)
Primary mining activity	Crushing/Grinding	53 (44.2)
	Excavation/Digging	31 (25.8)
	Ore Washing/Processing	21 (17.5)
	Transportation/Haulage	15 (12.5)
PPE use	None	63 (52.5)
	Occasional/Partial Use	35 (29.2)
	Regular Use	22 (18.3)

Prevalence of Occupational Health Symptoms

More than half of the respondents reported at least one respiratory symptom (55.8%), while musculoskeletal symptoms were reported by 65.0% of miners. Back pain and chronic cough were the most frequently reported complaints.

Table 2: Prevalence of Occupational Health Symptoms Among Respondents

Health outcome	n (%)
Chronic cough	58 (48.3)
Wheezing	46 (38.3)
Chest tightness	41 (34.2)
Back pain	72 (60.0)
Joint pain	64 (53.3)
Muscle strain	59 (49.2)

Table 2 indicates that occupational health symptoms were prevalent among artisanal miners. Specifically, respiratory complaints included chronic cough (48.3%), wheezing (38.3%), and chest tightness (34.2%). Musculoskeletal symptoms were even more prevalent, with back pain reported by 60.0% of miners, joint pain by 53.3%, and muscle strain by 49.2%. These findings collectively underscore a substantial burden of both respiratory and musculoskeletal health issues within the study population.

Association Between Mining Practices and Occupational Health Outcomes

Bivariate analysis revealed significant associations. Specifically, respiratory symptoms were significantly associated with long working hours, involvement in crushing/grinding activities, and non-use of personal protective equipment (PPE) ($p < 0.05$). Conversely, musculoskeletal symptoms demonstrated significant associations with long working hours, heavy manual lifting, and extended mining experience.

Table 3: Association Between Mining Practices and Occupational Health Outcomes

Predictor	Outcome	χ^2 (df)	p-value
Working hours (>8 hrs)	Respiratory symptoms	$\chi^2(1) = 8.74$	0.003
Crushing/grinding	Respiratory symptoms	$\chi^2(1) = 12.96$	<0.001
Education level	Respiratory symptoms	$\chi^2(2) = 3.45$	0.178
PPE non-use	Respiratory symptoms	$\chi^2(1) = 10.21$	0.001
Working hours (>8 hrs)	Musculoskeletal symptoms	$\chi^2(1) = 11.48$	0.001
Heavy manual lifting	Musculoskeletal symptoms	$\chi^2(1) = 9.67$	0.002
Education level	Musculoskeletal symptoms	$\chi^2(2) = 2.88$	0.236
Mining experience (≥2 yrs)	Musculoskeletal symptoms	$\chi^2(1) = 8.91$	0.003

Table 3 shows the bivariate associations between mining practices and occupational health symptoms. Respiratory symptoms were significantly associated with working more than eight hours per day ($\chi^2(1) = 8.74$, $p = 0.003$), crushing/grinding activities ($\chi^2(1) = 12.96$, $p < 0.001$), and non-use of PPE ($\chi^2(1) = 10.21$, $p = 0.001$). Musculoskeletal symptoms were significantly associated with long working hours ($\chi^2(1) = 11.48$, $p = 0.001$), heavy manual lifting ($\chi^2(1) = 9.67$, $p = 0.002$), and mining experience of two years or more ($\chi^2(1) = 8.91$, $p = 0.003$). These results indicate that specific occupational practices are linked to increased health risks among artisanal miners.

Multivariable Logistic Regression Analysis

Bivariate analysis revealed significant associations between selected mining practices and occupational health outcomes. Specifically, respiratory symptoms were significantly associated with long working hours, involvement in crushing/grinding activities, and non-use of personal protective equipment (PPE) ($p < 0.05$). Conversely, musculoskeletal symptoms showed significant associations with long working hours, heavy manual lifting, and extended mining experience. No significant association was observed between education level and either respiratory or musculoskeletal symptoms ($p > 0.05$).

Table 4: Multivariable Logistic Regression Analysis of Occupational Health Outcomes

Predictor	Outcome	AOR	95% CI	p-value
Working hours (>8 hrs vs ≤8 hrs)	Respiratory	2.41	1.18–4.93	0.016
Crushing/grinding (Yes vs No)	Respiratory	3.12	1.48–6.56	0.003
PPE non-use (None vs Any use)	Respiratory	2.87	1.36–6.05	0.006
Working hours (>8 hrs vs ≤8 hrs)	Musculoskeletal	2.96	1.41–6.23	0.004
Heavy manual lifting (Yes vs No)	Musculoskeletal	2.54	1.21–5.32	0.014
Mining experience (≥2 yrs vs <2 yrs)	Musculoskeletal	2.18	1.03–4.61	0.042

Table 3 shows the bivariate associations between mining practices, education level, and occupational health outcomes. Respiratory symptoms were significantly associated with working more than eight hours per day ($\chi^2(1) = 8.74$, $p = 0.003$), crushing/grinding activities ($\chi^2(1) = 12.96$, $p < 0.001$), and non-use of PPE ($\chi^2(1) = 10.21$, $p = 0.001$). Musculoskeletal symptoms were significantly associated with long working hours ($\chi^2(1) = 11.48$, $p = 0.001$), heavy manual lifting ($\chi^2(1) = 9.67$, $p = 0.002$), and mining experience of two years or more ($\chi^2(1) = 8.91$, $p = 0.003$). Education level was not significantly associated with either respiratory or musculoskeletal symptoms ($p > 0.05$). These results indicate that specific occupational practices, rather than educational status, are the primary factors linked to increased health risks among artisanal miners.

Model Adequacy

Table 5: Logistic Regression Model Diagnostics for Occupational Health Outcomes

Diagnostic Test	Respiratory Symptoms Model	Musculoskeletal Symptoms Model	Acceptable Criterion
Number of observations	120	120	–
Hosmer–Lemeshow χ^2	6.12	5.47	–
Hosmer–Lemeshow p-value	0.634	0.709	$p > 0.05$
Mean Variance Inflation Factor (VIF)	1.68	1.74	< 10
Maximum VIF	2.21	2.34	< 10

Table 5 demonstrates that both logistic regression models exhibited adequate fit. The non-significant Hosmer–Lemeshow tests ($p = 0.634$ and $p = 0.709$), coupled with all variance inflation factors remaining below 2.5, indicate the absence of multicollinearity. These findings collectively support the models' suitability for identifying predictors of occupational health risks.

Discussion

Among artisanal miners in Anka LGA, respiratory and musculoskeletal symptoms exhibited high prevalence. Specifically, chronic cough (48.3%) and back pain (60.0%) constituted the most frequently reported complaints. This pattern suggests a dual etiology, stemming from both occupational dust exposure and the physically demanding nature of their work. These findings are consistent with prior research in Nigeria and other African nations, which have similarly identified respiratory and musculoskeletal health problems among artisanal and small-scale mining (ASM) workers, frequently attributing these to exposure to dust, heavy metals, and repetitive physical tasks (Semiono *et al.,* 2023; Afolayan *et al.,* 2021; Ondayo *et al.,* 2023).

A multivariable analysis identified several occupational risk factors. Specifically, miners who worked more than eight hours daily, engaged in crushing/grinding activities, or did not utilize personal protective equipment (PPE) exhibited significantly higher odds of respiratory symptoms. Concurrently, prolonged working hours, heavy manual lifting, and a mining tenure exceeding two years were independently associated with musculoskeletal complaints. These findings are consistent with global evidence indicating that extended exposure to dust, repetitive physical labor, and insufficient protective practices substantially elevate occupational health risks within artisanal mining communities (Hilson, 2025; Tsang *et al.,* 2020).

The non-use of personal protective equipment (PPE) is associated with adverse respiratory outcomes, underscoring the necessity of protective measures in reducing exposure to airborne contaminants. These contaminants, which include dust and metals such as lead and mercury, have been documented at artisanal and small-scale mining (ASM) sites in Zamfara and other regions (Nota *et al.,* 2025; Allan-Blitz *et al.,* 2021). Furthermore, the combination of heavy manual labor and extended work hours contributes to musculoskeletal complaints among miners, reflecting the cumulative physical burden experienced. This observation aligns with findings from ergonomic assessments conducted in ASM communities (Paul *et al.,* 2024).

The finding that mining experience of two years or more significantly predicts musculoskeletal symptoms (AOR = 2.18, 95% CI: 1.03–4.61) may reflect cumulative physical exposure over time, where prolonged engagement in repetitive lifting, bending, and manual ore processing increases the risk of chronic musculoskeletal strain. However, it may also reflect a form of survival bias, where healthier individuals remain in mining for longer periods, while those with severe conditions exit the occupation earlier. Similar patterns have been noted in occupational health studies of informal labor sectors.

The gender distribution of the sample, where only 10% of respondents were female, limits the extent to which conclusions can be generalized to female miners. This reflects the male-dominated structure of artisanal mining in the study area, but it also highlights the need for caution in interpreting gender-related occupational health implications, as women's exposure patterns and risks may differ but are underrepresented in this dataset.

Model diagnostics confirmed the statistical soundness of the logistic regression models, which exhibited adequate fit and an absence of multicollinearity. This validates the reliability of the observed associations and strengthens confidence in the identified occupational risk factors.

An additional contextual consideration is the relatively low educational attainment among respondents, with 77.5% having no more than primary education. This has important implications for intervention design, as occupational safety training and health education programs must be tailored to low-literacy populations using practical demonstrations, visual tools, and local language communication rather than text-heavy materials.

The findings underscore the significant need for targeted occupational health interventions within Anka LGA. Implementation of measures such as enforcing personal protective equipment (PPE) use, regulating working hours, mechanizing dust-intensive activities, and providing ergonomic training could effectively mitigate respiratory and musculoskeletal health risks. These proposed interventions align with recommendations derived from

studies of artisanal mining communities throughout Nigeria and across the African continent (Afolayan *et al.,* 2021; Ondayo *et al.,* 2023).

This study is limited by its reliance on self-reported symptoms, which are susceptible to recall bias. A further limitation is the absence of direct environmental exposure measurements. Nevertheless, combining observational assessments with questionnaire data provides a reliable proxy for occupational risk. Future research incorporating biomonitoring and environmental sampling would strengthen causal inference.

CONCLUSION

The findings indicate a high prevalence of occupational health symptoms among artisanal miners in Anka LGA, Zamfara State, with most participants experiencing both respiratory and musculoskeletal complaints. The major risk factors identified include prolonged working hours, engagement in dust-intensive activities such as crushing and grinding, heavy manual lifting, and inadequate use of personal protective equipment (PPE). These results demonstrate that routine mining practices substantially contribute to adverse health outcomes in this population.

Beyond documenting these associations, the study adds to the growing evidence base on artisanal and small-scale mining (ASM) in Nigeria by providing localized empirical data linking specific occupational exposures to self-reported health outcomes. This strengthens the understanding of how everyday mining activities translate into measurable health burdens within rural mining communities.

Key limitations include the predominance of female underrepresentation (10%), which limits the generalizability of findings to women miners, as well as the reliance on self-reported symptoms without biomarker or environmental confirmation.

Overall, the study highlights the urgent need for practical occupational health interventions in ASM settings, particularly in Zamfara State and similar mining communities.

RECOMMENDATIONS

In line with the findings, the following measures are recommended to reduce occupational health risks among artisanal miners:

1. Enforcement and promotion of PPE use through provision of protective masks, gloves, and clothing, supported by continuous health and safety training.
2. Regulation of daily working hours to reduce cumulative physical strain and reduce prolonged exposure to dust.
3. Mechanization of dust-generating activities such as crushing and grinding to minimize direct manual exposure.
4. Provision of ergonomic training programs focusing on safe lifting techniques, posture control, and injury prevention.
5. Periodic environmental and health monitoring, including assessment of dust levels, air quality, and biomonitoring for heavy metals to guide interventions.
6. Development and enforcement of local occupational health policies informed by empirical evidence from ASM communities.

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