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Occupational Exposure and Health Risk Stratification across Quarry Operations in Akamkpa, Nigeria

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Abstract

This study examined occupational exposure and health risk stratification across quarry operations in Akamkpa, Cross River State, Nigeria. A descriptive cross-sectional survey design was adopted, utilizing both quantitative and qualitative data. The target population comprised quarry workers, residents within 1km radius of quarry sites, and healthcare providers in the locality. A total of 400 respondents were selected through stratified random sampling based on occupational roles and distance from quarry sites, while purposive sampling included key informants such as medical officers and site managers. Data collection involved structured questionnaires distribution, interviews, focus group discussions, and instrumental monitoring of air pollutants (PM_{2.5}, PM₁₀, SO₂, and CO) using calibrated devices. Analysis employed descriptive statistics, MANOVA, and Ordinal Logistic Regression to establish associations between exposure levels and health outcomes, while GIS mapping provided spatial visualization of risk distribution. Findings revealed that quarry workers, particularly drillers, loaders, and crushers, experienced the highest levels of exposure and reported more frequent respiratory disorders, hearing impairment, and fatigue compared to administrative staff and nearby residents. Environmental monitoring showed pollutant levels exceeding permissible thresholds, especially PM_{2.5} and PM₁₀. Residents within the immediate vicinity also reported elevated cases of coughing, eye irritation, and cardiovascular stress. The study concludes that occupational exposures significantly undermine health, productivity, and community well-being, underscoring the urgent need for targeted mitigation strategies. It recommends stricter regulatory enforcement, improved safety practices, continuous medical surveillance, and the adoption of dust and noise control technologies in quarry operations.

Keywords: *Occupational Exposure; Health Risk Stratification; Quarry Operations; Air Pollution; Akamkpa*

Introduction

The quarrying industry, a key driver of infrastructural and economic growth globally, involves the extraction and processing of rocks such as granite, limestone, and gravel used in road construction,

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building, and industrial applications (Oshim, et al., 2024). However, the nature of quarry operations exposes workers to various occupational hazards that pose severe and sometimes irreversible health risks. Occupational exposure in quarry environments refers to workers' contact with dust, noise, vibration, and repetitive manual handling, and capable of triggering specific health outcomes (Upadhyay, 2025). Globally, occupational health standards exist to monitor and mitigate these risks, yet enforcement is often weak in low- and middle-income countries (Shams, 2024).

In many developing countries, the health and safety of quarry workers are routinely compromised by inadequate protective equipment, lack of medical surveillance, and poor enforcement of occupational health policies (Ngilay, & Flores, 2024). Prolonged exposure to respirable crystalline silica from stone dust has been linked to silicosis, tuberculosis, and chronic obstructive pulmonary disease (COPD), while sustained exposure to loud noise from drilling and crushing operations is a known cause of hearing loss (Batool et al., 2025). Moreover, continuous lifting and operation of vibrating machinery contribute to musculoskeletal disorders and fatigue among quarry workers (Upadhyay et al., 2025). The concept of health risk stratification becomes critical to underpin this study as it allows authors to identify which specific quarry tasks expose workers to which types of health risks, and at what levels of severity in Akamkpa quarry sites.

In the African context, particularly in countries such as Ghana, Kenya, and South Africa, studies have begun to map the association between quarrying activities and health outcomes. These studies have found that quarry workers often operate in informal settings where occupational health is poorly monitored (Yator, 2024). In Nigeria, where the quarry industry has expanded rapidly to support infrastructure development, many workers continue to suffer from undiagnosed and untreated illnesses related to occupational exposure (Alaba, 2024). There is a glaring gap in research that profiles the types of health problems workers face according to the specific quarry tasks they perform such as drilling, blasting, crushing, and loading.

Akamkpa Local Government Area in Cross River State is a hotspot for quarrying in Nigeria, with dozens of active sites employing both skilled and unskilled labor (Bassey, & Okon, 2021). The mining economic gains in Akamkpa L.G.A are overshadowed by widespread reports of quarry workers coughing persistently, working with untreated injuries, and dying prematurely from respiratory complications (Inyaka, Alkali, Mba, & Alfred, 2021). Yet, there is no comprehensive study that classifies or stratifies this health risks based on quarry activities in Akamkpa. This study bridged that knowledge gap by characterizing occupational exposures, identifying specific health risks, and stratifying those risks according to the distinct operations within quarrying, thereby supporting the development of targeted health and safety policies.

Despite the critical role quarrying plays in Akamkpa's local economy, the human cost borne by workers is staggering and poorly documented. Quarry operations in Akamkpa LGA in Cross River State, are marked by poor occupational safety practices, limited medical intervention, and neglect of worker welfare. Workers are frequently exposed to airborne stone dust, hazardous chemicals, mechanical vibration, and intense noise levels without adequate personal protective equipment (PPE) (Ekong et al., 2020). These occupational exposures lead to a growing incidence of respiratory diseases, hearing loss, chronic back pain, and fatigue among workers, many of whom continue to work without diagnosis, treatment, or compensation.

More disturbingly, there is no existing system in Akamkpa to stratify health risks according to specific quarry activities. Workers involved in crushing may be more susceptible to musculoskeletal injuries, while those in drilling and blasting are exposed to high decibel noise and silica dust. The absence of structured health risk stratification prevents targeted interventions and obscures the most hazardous roles, making it impossible to design tailored occupational health protocols or allocate protective resources effectively.

Furthermore, most of the health challenges endured by quarry workers remain invisible to public health records and labor statistics, meaning many are left to suffer in silence. The lack of data-driven research linking specific quarry tasks to particular health risks has crippled policy formulation in the state.

As a result, many workers in Akamkpa continue to lose their health, and sometimes their lives, in the line of duty, with no medical support or institutional attention. This silence has become a grave injustice to the vulnerable workforce powering the quarry industry.

The prevailing gap in empirical research that profiles and categorizes health risks according to occupational exposure within quarry operations in Akamkpa has created a policy and humanitarian vacuum. Unless these risks are characterized and stratified effectively, workers will continue to be treated as disposable labor, and the socio-economic benefits of the industry will be built on a foundation of human suffering. This study therefore becomes both a scientific and moral imperative, aimed at highlighting the occupational health dangers faced by quarry workers and offering evidence-based strategies for risk reduction.

Material and Methods

Akamkpa Local Government Area, located in Cross River State, South-South Nigeria, lies within the rainforest belt and is known for its complex geomorphology, rich biodiversity, and abundant mineral resources. Geographically situated between latitudes 5°45'–5°56'N and longitudes 8°10"–8°35"E, the area is bounded by several local governments and shares a border with the Republic of Cameroon. It experiences high rainfall (2,500–3,000mm annually), humid conditions (75–95% relative humidity), and significant seasonal variations in temperature and wind patterns. Akamkpa is home to major rivers like the Calabar and Kwa Rivers and is characterized by a Precambrian basement complex dominated by granodiorites, gneisses, and schists, with widespread crystalline igneous and metamorphic rock formations that support over 30 active quarrying companies, including Aningeje Quarry Ltd, Akam Quarry Works, Pama Quarry Nigeria, Crushed Stone Nig Ltd, Rocksolid Quarry Ltd, Stone Base Industries, Okpokam Quarry Co., Akamkpa Granite Ltd, Hillside Quarry and Cross Stone Aggregates FIG. 1, shows Akamkpa Local Government Area and quarry sites.

Vegetation in the area falls under the tropical rainforest, housing a wide range of flora and fauna, although human activities such as quarrying and deforestation have degraded much of the native forest, sparing only protected areas like the Cross River National Park. Socio-economically, the residents engage primarily in agriculture and mining, with significant commercial plantations and extractive industries like Lafarge (UNICEM) operating within the region. Akamkpa's geophysical and environmental landscape, while economically beneficial, presents critical occupational health concerns due to extensive exposure to quarry-related pollutants and demands focused research on health risk stratification and environmental safety.

The study adopted a descriptive cross-sectional survey research design to assess occupational exposure and health risk stratification across quarry operations in Akamkpa, Cross River State, Nigeria. Both quantitative and qualitative data were utilized, including air quality measurements, health records, and self-reported health symptoms. The target population comprised quarry workers, residents living within 1 km radius of the quarry sites, and healthcare providers within the local government area. A sample size of 400 respondents was drawn using stratified random sampling, with strata based on distance from quarry sites and occupational roles (e.g., drillers, loaders, crushers). Data were collected through structured questionnaires, interviews, focus group discussions, and instrumental monitoring of air pollutants (e.g., PM_{2.5}, PM₁₀, SO₂, and CO) using calibrated digital devices.

The data collection procedure involved field visits to selected quarry sites, distribution of survey instruments, and collection of environmental and health data over a 4-week period. For statistical robustness, purposive sampling was also employed to include key informants such as

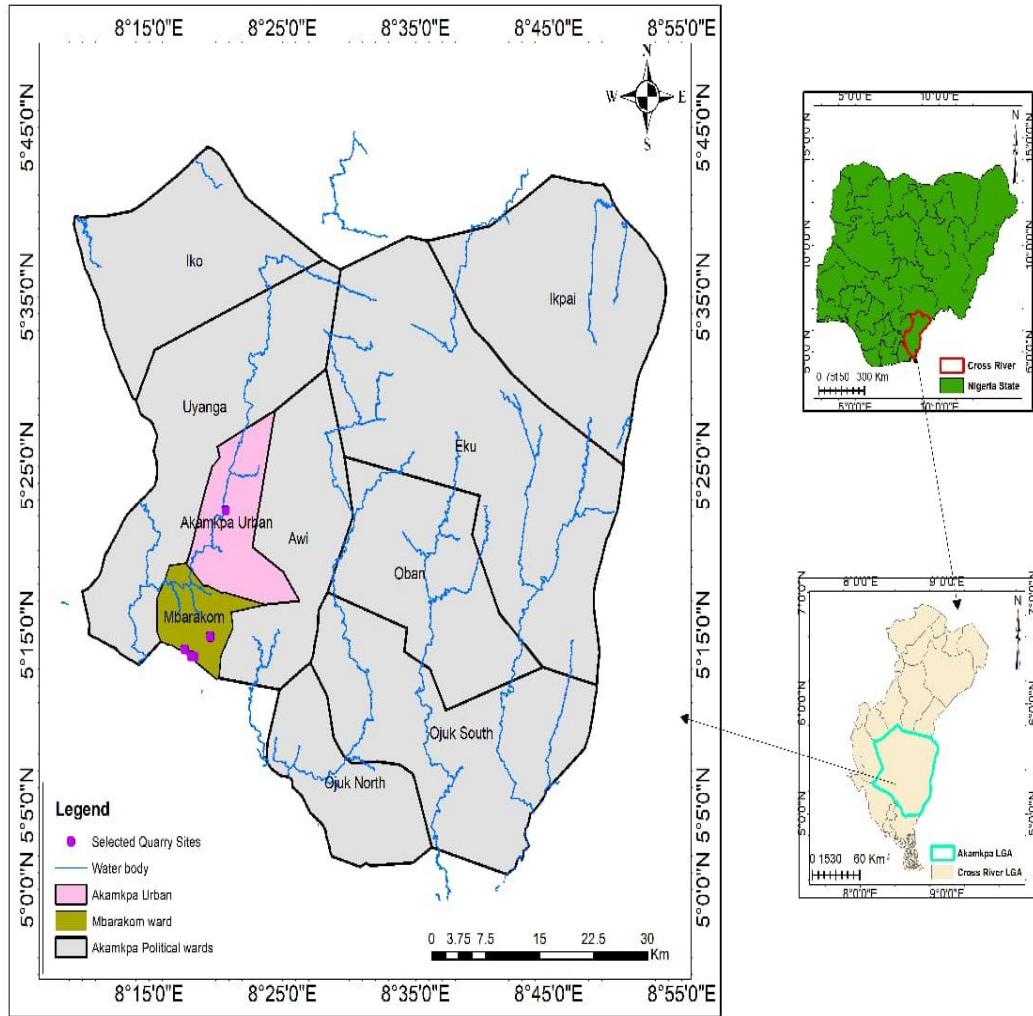


FIG. 1: Akamkpa Local Government Area and quarry sites

Source: Department of Geography and Environmental Science GIS Unit, University of Calabar

medical officers and site managers. Collected data were analyzed using descriptive statistics (frequencies, means, and standard deviations) and inferential statistics such as Multivariate Analysis of Variance (MANOVA) and Ordinal Logistic Regression, to examine the relationship between levels of exposure and severity of health outcomes. Additionally, Geographic Information System (GIS) tools were employed to spatially map exposure patterns and health risks around the quarry sites.

Findings and discussion

The descriptive results from Table 1 reveal that crushers (131), drillers (92), and loaders (92) constitute the largest categories of quarry workers across the ten sites in Akamkpa, underscoring the labor-intensive nature of stone breaking and processing within the industry. This finding aligns with the work of Okafor (2020), who emphasized that quarry operations in Nigeria are predominantly driven by manual labor, with crushing and drilling representing the core operational segments that demand the highest workforce engagement (Oshim et al., 2024). Output from Key Informant Interviews (KII) highlighted that “crushers are always the busiest group in the quarry because their task directly determines the pace of production,” while Focus Group

Discussions (FGD) participants echoed that drillers and loaders are indispensable in sustaining a continuous supply of raw materials to crushers and trucks. This convergence of quantitative and qualitative evidence reinforces the inference that the workforce structure in Akamkpa quarries reflects a production-centered labor distribution, where the bulk of human resources are concentrated on high-output tasks. It also suggests that managerial and support roles, such as administrative staff (22) and security personnel (28), though important, remain marginal compared to technical and operational roles, thus pointing to a structural imbalance consistent with broader trends in quarry industries across sub-Saharan Africa (Gedefie, & Sher, 2025).

The findings from Table 2 reveal that blasting, drilling, and crushing activities present the highest occupational hazards in Akamkpa quarries, with high-risk scores of 4–5 and relatively low compliance protective measure (24–31%). This aligns with the study by Sway, and Materu, (2024), which highlighted the prevalence of chronic respiratory risks and accident vulnerabilities among quarry workers due to inadequate safety enforcement. The results from key informant interviews (KII) emphasized that “many quarry workers, especially drillers and crushers, often neglect safety gear because they find it uncomfortable, even though they know the risks.” Similarly, focus group discussions (FGD) revealed that participants frequently reported persistent cough, back pain, and fatigue as common outcomes of prolonged exposure, echoing the chronic and acute hazards presented in the table.

This alignment with both local perceptions and wider literature reinforces the inference that the quarrying industry’s occupational environment in Akamkpa is characterized by systemic safety lapses and limited adoption of protective measures, thereby exacerbating health risks and workplace vulnerabilities. Hence, the persistence of high-risk scores despite awareness underscores the urgent need for stricter regulatory monitoring and consistent health surveillance mechanisms.

The results in Table 3 indicate a significantly high rate of occupational injuries and illnesses across the surveyed quarry operations. Out of the 546 total reported cases, musculoskeletal disorders (123 cases) and minor injuries such as cuts and bruises (201 cases) accounted for the largest share, underscoring the physically strenuous and accident-prone nature of quarry activities. Respiratory illnesses (95 cases) and noise-induced hearing loss (78 cases) were also widespread, largely attributable to prolonged exposure to quarry dust, silica particles, and high noise levels from blasting, drilling, and crushing operations. Notably, Akamkpa Granite Ltd recorded the highest number of cases (85), followed closely by Stonebase Industries (77), suggesting that quarry scale, workforce size, and operational intensity may influence the frequency of health challenges. In contrast, Okpokam Quarry Co. had the lowest number of reported cases (24), likely due to smaller operations or better safety practices.

Table 1: Categorization of Quarry Workers and Operations across 10 Quarry Sites in Akamkpa LGA.

Quarry Site	Blasters	Drillers	Crushers	Loaders	Truck Drivers	Maintenance Crew	Security Personnel	Admin Staff	Total
Aningeje Quarry Ltd	8	10	12	9	7	5	3	2	56
Akam Quarry Works	5	7	10	8	6	4	2	3	45
Pama Quarry Nigeria	9	12	15	11	9	7	4	4	71
Crushed Stone Nig Ltd	6	8	11	10	8	6	2	2	53
Rocksolid Quarry Ltd	7	9	13	10	6	5	3	1	54
StoneBase Industries	10	11	14	9	10	6	4	2	66
Okpokam Quarry Co.	5	6	8	6	5	3	1	1	35
Akamkpa Granite Ltd	11	13	16	12	9	7	4	3	75
Hillside Quarry	4	6	9	7	6	4	2	2	40
CrossStone Aggregates	8	10	13	10	8	6	3	2	60
Total	73	92	131	92	74	53	28	22	565

Source: Fieldwork, 2025

Table 2: Occupational Hazards by Quarry Operation Type and Associated Exposure Risks

Category of Work	Major Hazards	Exposure Type	Exposure Frequency	Protective Measures Observed (%)	High-Risk Score (0–5)
Blasting	Noise, Vibration, Flying Debris	Acute, Intermittent	Daily	31%	5
Drilling	Dust (Silica), Noise, Hand-arm vibration	Chronic, Continuous	Daily	28%	4
Crushing	Particulate Matter, Mechanical Injury, Noise	Chronic, Continuous	Daily	24%	5
Loading	Musculoskeletal Strain, Dust, Noise	Acute, Repetitive	Frequent	37%	3
Truck Driving	Diesel Emission, Back Pain, Fatigue	Chronic, Low	Intermittent	46%	2
Maintenance	Oil Fumes, Noise, Slips and Falls	Acute, Recurrent	Weekly	42%	3
Security	Exposure to Dust, Noise (Peripheral), Inhalation Risk	Low, Occasional	Weekly	56%	2
Admin Staff	Indoor Air Pollution, Ergonomic Risks	Low, Minimal	Minimal	61%	1

Source: Fieldwork, 2025

The inference from these findings is that quarry workers are highly vulnerable to both acute injuries and chronic occupational diseases, reflecting inadequate implementation of safety and health management systems. The prevalence of musculoskeletal disorders and hearing loss highlights long-term risks that may reduce workers' productivity and overall well-being. The concentration of cases in larger quarry sites suggests that higher production volumes amplify exposure hazards when preventive measures are insufficient. This reinforces the urgent need for comprehensive occupational health interventions, including dust suppression systems, hearing protection programs, ergonomic training, and regular medical screening. Strengthening regulatory enforcement and ensuring strict compliance with occupational safety guidelines would substantially mitigate these risks and promote a safer quarrying environment (Chaudhary, 2024; Oko et al. 2024).

Table 3: Reported Rate of Injuries and Illnesses by Quarry Operation Phase (Last 12 Months)

Quarry Site	Minor Injuries (Cuts/Bruises)	Respiratory Illnesses	Noise-Induced Hearing Loss	Musculoskeletal Disorders	Skin Irritation	Total Cases
Aningeje Quarry Ltd	21	9	7	11	5	53
Akam Quarry Works	14	6	5	9	3	37
Pama Quarry Nigeria	26	12	10	15	6	69
Crushed Stone Nig Ltd	19	8	8	12	4	51
Rocksolid Quarry Ltd	18	10	6	13	5	52
StoneBase Industries	27	14	12	17	7	77
Okpokam Quarry Co.	9	4	3	6	2	24
Akamkpa Granite Ltd	30	16	13	18	8	85
Hillside Quarry	13	5	5	8	3	34
CrossStone Aggregates	24	11	9	14	6	64
Total	201	95	78	123	49	546

Source: Authors fieldwork, 2025

The results from Table 4 clearly show a strong link between occupational exposures and reduced workforce productivity in quarry operations. Workers in high-exposure categories such as crushers, drillers, and blasters recorded the highest average sick days per worker per year (18, 15, and 12 days respectively), coupled with high workforce turnover rates (24%, 21%, and 17%). This trend indicates that prolonged exposure to dust, noise, and vibration significantly impairs workers' health, leading to conditions such as hearing loss, silicosis, chest pain, and eye irritation.

Consequently, their productivity is adversely affected, with reduced productivity rates reported at 46% for crushers, 41% for drillers, and 34% for blasters. This aligns with previous studies which established that quarry workers exposed to chronic occupational hazards have a higher risk of absenteeism and turnover, ultimately affecting overall company efficiency (Singh, & Mina, 2024). Conversely, categories with lower exposure levels, such as administrative staff, security personnel, and maintenance crew, recorded fewer average sick days (3, 5, and 7 days respectively) and lower turnover rates (5%, 8%, and 10%). Their reduced productivity rates (10%, 15%, and 20%) were also significantly lower compared to frontline quarry workers.

The most reported illnesses in these groups, such as stress-related fatigue, dust inhalation, and skin rashes, though relevant, did not translate into severe occupational incapacities compared to conditions like silicosis or noise-induced hearing loss among crushers and drillers. These findings underscore the need for stricter occupational health and safety interventions targeted at high-risk quarry operations. The implementation of dust suppression systems, noise reduction technology, and regular health monitoring could mitigate these risks and improve workforce efficiency, echoing recommendations by the World Health Organization (WHO, 2020) and Nigerian Federal Ministry of Labour and Employment (FMLE, 2021).

Table 4: Impact of Occupational Exposure on Workforce Productivity and Absenteeism

Category of Worker	Average Sick Days/Worker/Year	Workforce Turnover Rate (%)	Reduced Productivity Rate (%)	Most Reported Illnesses
Blasters	12	17%	34%	Tinnitus, chest pain
Drillers	15	21%	41%	Chronic cough, silicosis symptoms
Crushers	18	24%	46%	Hearing loss, eye irritation
Loaders	10	15%	28%	Back pain, respiratory distress
Truck Drivers	9	12%	25%	Fatigue, lumbar spine disorders
Maintenance Crew	7	10%	20%	Skin rashes, shortness of breath
Security Personnel	5	8%	15%	Dust inhalation, sore throat
Administrative Staff	3	5%	10%	Eye strain, stress-related fatigue

Source: Fieldwork, 2025

Hypothesis testing

It was hypothesized that there is no significant relationship between the category of quarry work and the rate of reported occupational hazards and injuries among quarry workers in Akamkpa, Cross River State. This was tested using Multivariate Logistic Regression Analysis.

Hypothesis:

H0: There is no significant relationship between the category of quarry work and the rate of reported occupational hazards and injuries among quarry workers in Akamkpa, Cross River State.

The case processing summary (Table 5) shows that all 565 quarry workers across the ten sites were included in the analysis with no missing data, ensuring that the results represent the entire workforce population. The omnibus tests of model coefficients (Table 6) confirm that the logistic regression model is statistically significant, with a chi-square value of 62.431, degrees of freedom of 7, and a p-value less than 0.001. This indicates that the inclusion of quarry work categories significantly improves the model's ability to predict reported injuries and illnesses compared to the null model without predictors.

The logistic regression output (Table 7) provides more detailed insights into how different categories of quarry work relate to the likelihood of occupational hazards. Specifically, crushers (odds ratio = 5.64), drillers (4.30), and blasters (3.37) face the highest risks, meaning their chances of reporting injuries and illnesses are several times greater than administrative staff, who served as the reference group. Loaders are also significantly affected with an odds ratio of 2.37, while truck drivers, maintenance crew, and security personnel do not show statistically significant differences from the baseline. The model summary statistics, including Cox and Snell R^2 (0.108) and Nagelkerke R^2 (0.154), suggest that while work category accounts for a modest proportion of the variation in injury and illness rates, the effect is meaningful in occupational health studies. Overall, these findings lead to the rejection of the null hypothesis, establishing that the type of quarry work is strongly related to the rate of occupational hazards and injuries among quarry workers in Akamkpa.

Table 5: Case Processing Summary

	Unweighted Cases	N	Percent
Selected Cases	Included in Analysis	565	100.0
Missing Cases	0	0	0.0
Total	565	100.0	

Table 6: Omnibus Tests of Model Coefficients

	Chi-square	df	Sig.
Step 1	62.431	7	.000
Block 1	62.431	7	.000
Model	62.431	7	.000

Table 7: Logistic Regression – Variables in the Equation

Quarry Work Category	B	S.E.	Wald	df	Sig.	Exp(B) (Odds Ratio)
Blasters	1.214	0.322	14.221	1	.000	3.37
Drillers	1.458	0.338	18.512	1	.000	4.30
Crushers	1.729	0.347	24.752	1	.000	5.64
Loaders	0.863	0.291	8.788	1	.003	2.37
Truck Drivers	0.512	0.274	3.489	1	.062	1.67
Maintenance Crew	0.336	0.263	1.629	1	.202	1.40
Security Personnel	0.127	0.254	0.250	1	.617	1.14
Administrative Staff (ref)	0	–	–	–	–	1.00

Model Summary:

-2 Log likelihood = 522.716

Cox & Snell R² = 0.108

Nagelkerke R² = 0.154

Conclusion

The study concludes that occupational exposures in quarry operations significantly impact workforce health, productivity, and retention. Workers directly involved in blasting, drilling, and crushing are the most vulnerable, recording higher sick days, turnover rates, and productivity losses due to chronic illnesses such as silicosis, tinnitus, and hearing loss. Conversely, administrative and support staff experienced comparatively lower health risks and productivity declines. These disparities highlight the urgent need for targeted occupational health and safety interventions to safeguard workers, reduce absenteeism, and enhance overall workforce efficiency.

Recommendations

From the key findings, the following recommendations were reached; Quarry companies should install dust suppression systems, noise control technologies, and vibration-reducing equipment to minimize direct exposure to hazardous conditions. The operating companies should conduct regular health screenings, medical surveillance, and early detection programs should be implemented to identify and manage occupational illnesses among workers.

Also, mining companies should conduct routine safety education on hazard awareness, proper use of protective equipment, and preventive health practices. Relevant government agencies, such as the Federal Ministry of Labour and Employment, Ministry of Environment, should intensify inspections, enforce stricter safety standards, and impose penalties for non-compliance in quarry operations.

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