

Appraising the Impact of Granite Quarrying on the Magashanu Community in Kaduna State, Nigeria

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Abstract

This study is aimed at appraising the environmental and socio-economic impacts of granite quarrying on Magashanu community in Kaduna State, North-western Nigeria. Representative samples of soil and water were collected from within the community, alongside rock samples obtained from Tutu and Datum quarries, and subjected to laboratory analysis. Atomic Absorption Spectrometry (AAS) was employed to evaluate heavy metal concentrations in water and soil, while X-Ray Fluorescence (XRF) was used to determine the lithochemical composition of rock samples. Data from field surveys, including questionnaires, oral interviews, and visual assessments, were complemented by secondary sources and analyzed. Findings revealed that most heavy metal concentrations, including Fe, Co, Cu, Cr, Cd, Zn, and Mn, were within the World Health Organisation (WHO) permissible limits in soil and water samples. However, lead (Pb) concentrations in soil averaged 0.58 ppm, exceeding the WHO threshold of 0.15 ppm, indicating potential long-term environmental and health risks. Silicon content in quarry rock samples ranged from 50% - 58%, suggesting a significant risk of silica dust inhalation with prolonged exposure. Beyond chemical contamination, community feedback and field observations highlighted persistent environmental nuisances, including dust emissions, noise pollution, ground vibrations, and structural damage to buildings. The study highlights growing community concerns over environmental degradation and inadequate corporate social responsibility (CSR) from quarry operators. Hence, improved environmental management, enhanced regulatory enforcement, and strengthened stakeholder engagement are critical for mitigating quarry-related impacts and fostering sustainable coexistence between the industry and host communities.

Keywords: Granite quarrying; heavy metals; silica dust; corporate social responsibility.

1.0 Introduction

Granite quarrying is a vital segment of the extractive industry, underpinning infrastructure development through the supply of construction aggregates. Driven by increasing demand for aggregates and stone in the construction of roads, buildings, and urban infrastructure, granite quarrying has witnessed a significant rise in production and distribution. This surge has resulted in the proliferation of quarry sites, particularly in areas with abundant granite outcrops and in proximity to expanding urban centres and rural communities (Oshim *et al.*, 2024; Chigonda, 2010; Abere *et al.*, 2020).

Mosch *et al.* (2011) said the quarrying process predominantly employs open-pit or strip-mining techniques to extract large granite deposits. Two primary products (crushed stone and dimension stone) are derived from this operation. Crushed stone serves as a fundamental aggregate in road construction, concrete works, and as a base material for various civil engineering applications. Dimension stone, on the other hand, involves the extraction of sizable, uniform rock blocks intended for architectural and decorative purposes such as building facades, curbing, counter tops, flagstones, roofing, and monumental structures. These blocks are often processed into large rectangular slabs, which are subsequently cut into smaller, uniformly shaped units to meet specific construction and design needs (Bergeson and Ernst, 2015).

Moreover, the production of crushed and broken stone, ranging from gravel to quarry dust, extends its applications to the chemical industry, paint formulation, and metallurgical processes (Prochorov, 2023). In communities like Magashanu in Kaduna State, where such quarrying activities are increasingly concentrated, the environmental, socio-economic, and land-use implications have become more pronounced. However, Saka and Hashim (2024) opined that the growing concentration of granite quarrying activities and their associated socio-economic and ecological consequences underscore the need for a comprehensive appraisal of these impacts to support sustainable resource management and inform policy interventions.

Once granite outcrops are identified in a quarrying zone, the extraction process typically begins with drilling and blasting operations to fragment the solid rock mass. This method is essential not only for granite but also for other hard rock formations such as sandstone and limestone, which often require preliminary

fracturing before excavation can occur (Feng *et al.*, 2022). Where the overburden is too thick to be removed directly with the excavation equipment, controlled blasting can be employed to reach the mineral deposit (Lienhart, 2013; Roy, 2019; Verma *et al.*, 2021). While blasting is effective in dislodging rock for further crushing and processing, it is also accompanied by the release of high-temperature and high-pressure energy arising from explosive detonation (Sanchidrián *et al.*, 2007). Although a substantial portion of this energy contributes to the intended rock fragmentation, a considerable fraction is dissipated as waste in the form of ground vibrations, noise, heat, airborne dust, and noxious gases (Daramola and Imoukhuede, 2014; Lozada *et al.*, 2010). These by-products of blasting operations are responsible for several adverse environmental and social impacts, including structural damage to buildings, disturbance to farmlands, degradation of local air quality, and general landscape destabilization issues that are increasingly evident in host communities such as Magashanu in Kaduna State.

Beyond the direct impacts of blasting, the machinery and operational systems used in granite quarrying also exert significant environmental pressure. The range of quarrying equipment and their accessories, depending on their operating mechanisms, frequency, and intensity of use, contribute cumulatively to environmental degradation (Taiwo and Ogunbode, 2024; Okafor *et al.*, 2023; Oshim *et al.*, 2024; Kafu-Quvane and Mlaba, 2024). Core activities such as rock drilling, wedging, cutting, and fracturing often result in severe land disturbance, leaving once-productive land barren or transforming it into uneven, hazardous terrains that restrict agricultural and residential usability. Furthermore, processes like stone crushing, truck loading, and transportation frequently release large volumes of dust into the atmosphere, especially under windy conditions, intensifying particulate matter emissions and deteriorating ambient air quality (Sairanen and Rinne, 2019; Srivastava and Elumalai, 2021; Sairanen *et al.*, 2018; Amitshreeya and Panda, 2012).

These environmental disturbances often extend beyond physical alteration of the landscape. They can result in long-term socio-ecological damage, impacting water bodies, biodiversity, built infrastructure, and the health and well-being of community residents. In this context, the cumulative effects of quarrying activities necessitate not only environmental consideration but also socio-economic evaluation to ensure balanced development. While granite quarrying generates substantial economic benefits, including employment opportunities and revenue through local and national channels, it also imposes long-lasting costs on ecosystems and livelihoods (Oshim *et al.*, 2024; Turyahabwe *et al.*, 2021).

Globally, environmental governance frameworks emphasize the need for robust regulatory mechanisms to ensure extractive activities do not undermine ecological stability. Instruments such as environmental impact assessments (EIAs), legal enforcement, and policy monitoring are core to such frameworks (Bekhechi and Merder, 2002; Edo, 2012). In Nigeria, this responsibility is distributed across several ministries, departments, and agencies (MDAs) tasked with ensuring quarry operations comply with sustainability standards in alignment with global best practices (Oruonye and Ahmed, 2020). This study aims to assess the impact of granite quarrying on the Magashanu community in the Kujama area of Kaduna State, North-western Nigeria.

1.1 Location and Accessibility of the Study Area

Magashanu village is located in the Chikum Local Government Area (LGA) of Kaduna State, in Northwestern Nigeria (Figs. 1 and 2). Two quarries operate in the community: Datum Construction Company and Tutu Tutu Quarries Limited, both of which are situated adjacent to each other. The village is located approximately on the geographical coordinates of 10° 29' 27.612" N and 7° 37' 17.088" E, respectively (Fig. 3). The nearest central town to Magashanu is Kujama, a key transit point along the Kaduna-Kachia Road. The community is accessible via the Kaduna-Kachia highway, a major road connecting Kaduna to the southern parts of the state, which is approximately 25–30 km away by road transportation.

1.2. Geology of the Area

The geology of the Magashanu community is characterized by subsurface layers of various soils, including weathered and fractured sandy soil, coarse-grained sands, and gravels, as well as a fresh basement of porphyritic granite with an average thickness of 42 metres and resistivity values ranging from 350 m to 774 m (Kure et al., 2019). The area lies within the geological framework of the Nigerian Basement Complex. This region is characterized by Precambrian crystalline rocks that have undergone significant weathering and structural modifications over geological time (Ocheja et al., 2021; Abdulmalik and Ahmed, 2024; Aboh et al., 2016; Yusuf et al., 2018; Jatau et al., 2013).

The structural geology and hydrogeology of the area show the presence of fractured layers which suggests past tectonic activity, which has created secondary porosity in the otherwise impermeable basement rocks (Odey et al., 2021). These fractures facilitate groundwater percolation, making the weathered and sandy layers viable sources for shallow wells and boreholes. The coarse sands and gravels serve as productive aquifers, while the porphyritic granite basement forms the lower boundary of the groundwater system (Vivan et al., 2023; Alimi et al., 2022). These geological features have, no doubt, contributed to the area's sustainable water resource management, agriculture, and infrastructure development.

2.0 Materials and Methods

The fieldwork for this study comprised systematic sample collection and on-site environmental assessment to evaluate the impact of granite quarrying on the Magashanu community. Rock, soil, and water samples were collected using a randomized sampling approach, with rock and soil samples obtained at regular spatial intervals across designated transects within the quarry-affected zones. Water samples were collected from major surface water bodies within the study area at three strategic points: the riverbank (entry), midstream, and downstream (exit) locations to ensure representative coverage of water quality dynamics.

These field observations were complemented by detailed physical assessments of visible environmental disturbances, including land degradation, dust dispersion, and water turbidity. All collected samples were subsequently subjected to standardized laboratory analyses.

A comprehensive field investigation was conducted in the Magashanu community to assess the environmental impacts of granite quarrying activities carried out by two major operators, Datum and Tutu Construction and Quarrying Companies. The study focused on evaluating key environmental stressors, including water pollution, ground vibrations, and noise disturbances, that affect the host community. Primary data were collected through a combination of field measurements, structured questionnaires, visual inspections, direct personal observations, and oral interviews with residents and quarry workers.

To support empirical assessment, three representative samples were randomly collected from different locations across the Magashanu community and the operational sites of both quarrying companies, each comprising soil, rock, and water. The sampling covered both quarried and unquarried zones, as well as surface water bodies within the vicinity. These samples were subsequently transported to the laboratory for physicochemical and geochemical analysis.

The fieldwork also incorporated visual assessments and physical inspections to document the observable effects of quarrying on nearby residential buildings, vegetation, and local watercourses. Particular attention was paid to structural damage, deforestation, and water turbidity. Additionally, the physical condition and appearance of quarry workers and nearby residents were noted as supplementary indicators of environmental and occupational exposure. Table 1 presents the types of samples collected and their corresponding geographic coordinates within the study area.

Table 1: Sample Type and Location Coordinates in Magashanu Community

Sample	Sample Type	Location Coordinates
WS 1	Water	N10° 29'32.7"; E007° 37'18.1"
WS 2	Water	N 10° 29'33.2"; E007° 37'19.1"
WS 3	Water	N 10° 29'31.8"; E007° 37'21.9"
SS 1	Soil	N 10° 29'30.7"; E007° 37'16.7"
SS 2	Soil	N 10° 29'28.0"; E 007° 37'16.9"
SS 3	Soil	N 10° 29'13.4"; E007° 37'18.1"
RS1 Datum	Rock	N 10° 29'12.1"; E007° 37'34.5"
RS2 Datum	Rock	N 10° 29'11.7"; E007° 37'31.5"
RS3 Datum	Rock	N 10° 29'15.2"; E007° 37'30.7"
RS 1 Tutu	Rock	N 10° 29'15.5"; E007° 37'15.0"
RS 2 Tutu	Rock	N 10° 29'15.6"; E007° 37'14.8"
RS 3 Tutu	Rock	N 10° 29'33.2"; E 007° 37'12.5"

2.1. Laboratory Analysis and Sample Preparation

The laboratory analysis focused on rock, soil, and water samples collected from various locations within the study area. Elemental and mineralogical characterization of the rock and soil samples was conducted using X-ray Fluorescence (XRF) and X-ray Diffraction (XRD), respectively. These techniques enabled the identification and quantification of major and trace elements, as well as the crystalline phases present in the samples. Water samples were analyzed using atomic absorption spectrometry (AAS) to determine the concentrations of heavy metals and other potentially toxic elements. All rock samples were transported to the laboratory within 24 hours of collection to preserve their integrity and minimize contamination. The mineralogical composition of the rock samples was further examined through XRD (X-ray Powder Diffraction) analysis, providing detailed insight into the lithological characteristics and potential environmental risks associated with the materials extracted from the quarry sites.

2.2. Complementary Analysis

A set of questionnaires was designed and administered to the residents of the Magashanu community to gather their opinions on the environmental effects of granite quarrying in the area. Eighty (80) copies of the questionnaire were administered to the respondents, 72 were retrieved, while 8 could not be retrieved. Seventy-two (72) copies of the questionnaire retrieved were acceptable for further analysis. The data were then analyzed using Microsoft Excel. In addition to the oral interview, which complemented questionnaire administration, visual observation and physical assessment were also used to examine the physical impact of granite quarrying on the environment.

3.0 Results and Discussion

3.1 Soil Contamination Assessment

As shown in Table 2, the Atomic Absorption Spectrometry (AAS) analysis of soil samples from the Magashanu community revealed significant concentrations of several heavy metals. Iron (Fe) levels were notably high across all samples (28.750 to 33.500 ppm), indicating natural lithogenic sources that were likely intensified by quarry-related disturbances, such as blasting and excavation. The findings from this study conformed with those of several research groups (Bakouan *et al.*, 2025; Mielki *et al.*, 2016; Coward *et al.*, 2017; Löhr *et al.*, 2013; Joseph *et al.*, 2020). Manganese (Mn) also presented elevated levels (0.877 to 2.273 ppm), exceeding typical background concentrations and raising concerns about bioavailability, groundwater migration, and potential uptake by crops. Lead (Pb) was recorded in the range of 0.400 to 0.768 ppm, indicating moderate contamination levels that could result in cumulative human exposure through ingestion of contaminated soil or inhalation of contaminated dust. These findings align with those of Darma *et al.* (2022), Kumar *et al.* (2020), Kumar *et al.* (2022), Ahmed *et al.* (2024), and Bahiru (2020), who similarly reported the leaching of heavy metals from mining sites as a consequence of insufficient environmental mitigation measures. Zinc (Zn) and chromium (Cr), particularly in Sample C (Zn: 0.616 ppm, Cr: 0.437 ppm), suggest anthropogenic influences possibly related to equipment wear and the use of blasting materials. Although copper (Cu) and cadmium (Cd) were detected in trace quantities (Cu: 0.168-0.256 ppm), their presence is nonetheless noteworthy due to their high toxicity and potential for long-term accumulation in soil and biota.

Table 2: Results of Magashanu Soil Analysis by AAS

S/N	Elements (ppm)	Sample A	Sample B	Sample C
1	Co (cobalt)	0.131	0.079	0.142
2	Fe (iron)	30.465	28.750	33.600
3	Pb (lead)	0.563	0.400	0.768
4	Cu (copper)	0.168	0.160	0.256
5	Zn (zinc)	0.639	0.470	0.616
6	Cr (chromium)	0.212	0.046	0.437
7	Cd (cadmium)	TRACES	TRACES	TRACES
8	Mn (manganese)	1.214	0.877	2.273

3.2 Water Quality Assessment

Water samples collected from the vicinity of the quarry operations, as shown in Table 3, exhibited detectable levels of heavy metals, albeit at lower concentrations than those found in the soil. Iron was again prominent, with the highest concentration in Sample B (0.249 ppm), likely sourced from runoff and sediment mobilization. Lead (Pb) ranged between 0.041 and 0.048 ppm, exceeding the WHO drinking water limit of

0.015 ppm, thus posing a direct health risk of neurological disorders, which aligns with the findings by Vivan *et al.* (2023).

Table 3: Results of Magashanu Water Analysis by AAS

S/N	Elements(ppm)	Sample A	Sample B	Sample C
1	Co (cobalt)	0.082	0.070	0.069
2	Fe (iron)	0.152	0.249	0.034
3	Pb (lead)	0.048	0.041	0.154
4	Cu (copper)	TRACES	TRACES	0.057
5	Zn (zinc)	TRACES	TRACES	TRACES
6	Cr (chromium)	TRACES	TRACES	TRACES
7	Cd (cadmium)	TRACES	TRACES	TRACES
8	Mn (manganese)	0.169	TRACES	TRACES

The presence of copper, zinc, cadmium, and chromium in trace quantities further indicates diffuse contamination, with manganese detected at 0.169 ppm in Sample A. These findings suggest that even low-level contamination can pose long-term environmental and health hazards, particularly in the context of chronic exposure and bioaccumulation in aquatic ecosystems, as confirmed by Sairanen and Rinne (2019). Hence, the corrosion potential, showing variable Fe levels (0.034–0.249 ppm), may accelerate pipe degradation, as observed in Nigerian groundwater systems (Alimi *et al.*, 2022).

3.3 Lithochemical Composition of Datum and Tutu Quarry Rocks

X-Ray Fluorescence (XRF) analysis results of rock samples shown in Table 4 from the Datum Quarry revealed that silicon (Si) was the most abundant element (57.63% to 59.48%), confirming the granite-dominated lithology of the site. Aluminium (Al: 12.20% to 16.24%) and potassium (K: 6.45% to 11.06%) further support the presence of aluminosilicate minerals such as feldspar and mica.

Table 4: Results of Rock Analysis of Datum Quarry Samples by XRF

Elements (%)	Sample 1	Sample 2	Sample 3
AL	12.2018	16.2493	14.9715
Si	58.1543	59.4833	57.6345
K	6.4546	11.0652	11.5579
Ca	2.7391	1.5611	7.0272
Ti	0.1095	0.5409	0.1144
Mn	0.0132	0.0114	0.0405
Fe	3.9893	1.6798	5.4310
Sr	0.0173	0.0204	0.0145
Nb	0.0148	0.0137	0.0131
Ag	0.090	0.0060	0.0084
Cd	0.0278	N.D.	0.0095
Pb	0.0054	0.0017	0.0050
Mo	0.0103	0.0021	0.0084
Sb	0.0043	0.0030	N.D.
Hf	N.D.	N.D.	0.0003

Other elements, such as calcium (Ca), iron (Fe), and titanium (Ti), were detected in moderate amounts, suggesting the presence of accessory minerals like biotite and hornblende. Trace metals, including lead (Pb), cadmium (Cd), silver (Ag), and molybdenum (Mo), were also present. Although individually low in concentration, their cumulative effects from weathering and dust dispersal could contribute to contamination of surrounding environments.

Hence, Table 5 shows that the Tutu Quarry exhibited similar lithological characteristics to the Datum Quarry, with silicon concentrations ranging from 47.76% to 57.09%, and aluminium content ranging from 11.17% to 13.96%. Potassium levels were consistently high (9.45% to 11.67%), reaffirming the granite signature of the deposit. Notably, iron content peaked at 12.286% in Sample 3, indicating local enrichment that may influence soil pH and redox conditions (Sanchidrián *et al.*, 2007).

Table 5: Results of Rock Analysis of Tutu Quarry by XRF

Elements (%)	Sample 1	Sample 2	Sample 3
AL	13.9610	12.5066	11.1724
Si	57.0851	47.4670	47.7642
K	11.6715	9.4546	10.7955
Ca	2.6712	5.6517	7.8686
Ti	0.0760	3.1134	0.1115
Mn	0.0087	0.0100	0.0259
Fe	5.8464	6.9328	12.2860
Sr	0.0112	0.0149	0.0072
Nb	0.0113	0.0140	0.0124
Ag	0.0063	0.0047	0.0059
Cd	0.0260	0.0199	0.0163
Pb	0.0032	0.0034	0.0043
Mo	N.D.	0.0027	N.D.
Sb	N.D.	N.D.	0.0188
Hf	N.D.	N.D.	0.0003

Trace metals, including cadmium (up to 0.0260%), lead (0.0043%), antimony (0.0188%), and silver, were detected. The presence of antimony is particularly significant due to its inclusion on global priority pollutant lists (Sairanen *et al.*, 2018). Though molybdenum (Mo) and hafnium (Hf) were either undetected or found in trace quantities, their detection indicates broader geochemical variability that could influence contaminant mobility during quarrying operations (Oshim *et al.*, 2024).

3.4 Comparison with WHO Guidelines

The comparison of the analyzed results with the global standard based on WHO guidelines, as shown in Table 6, reveals that several metal concentrations in both soil and water samples exceeded permissible limits as follows:

- i. Cobalt (Co): Soil concentrations (0.11 ppm) surpassed WHO limits (0.05 ppm), while water concentrations (0.073 ppm) remained within acceptable levels.
- ii. Iron (Fe): Although water concentrations (0.145 ppm) were below WHO thresholds, soil concentrations (30.9 ppm) were markedly high, potentially impairing nutrient dynamics in the rhizosphere.
- iii. Lead (Pb): Both soil (0.58 ppm) and water (0.081 ppm) levels exceeded WHO limits, raising red flags for both agronomic and public health concerns.
- iv. Zinc (Zn): Elevated in both matrices (soil: 0.58 ppm; water: -0.29 ppm), indicating anthropogenic input and potential ecological imbalance.
- v. Chromium (Cr): Soil concentrations (0.23 ppm) were over twice the WHO safe limit, with water concentrations also elevated.
- vi. Manganese (Mn): Soil levels (1.45 ppm) exceeded WHO limits, with water concentrations close to threshold levels. These findings suggest that quarry operations in this area have contributed to metal enrichment in the local environment, warranting strict monitoring and targeted remediation strategies. This difference aligns with Kafu-Quvane and Mlaba (2024), highlighting the distinction between perceptual and empirical assessments in quarry zones.

Table 6: Comparison of Results with WHO Limits

Metals	Mean concentration of water samples (ppm)	Mean concentration of soil samples (ppm)	WHO limits	Remarks
Co (cobalt)	0.073	0.11	0.5	Water below, soil above
Fe (Iron)	0.145	30.9	1.0	Water below, soil above
Pb (Lead)	0.081	0.58	0.15	Water below, Soil above.
Cu (copper)	-0.02	0.19	1.0	Water below,

Metals	Mean concentration of water samples (ppm)	Mean concentration of soil samples (ppm)	WHO limits	Remarks
				Soil below.
Zn (Zinc)	-0.29	0.58	0.001	Water below, soil above.
Cr (Chromium)	-0.136	0.23	0.1	Water below, Soil above.
Cd (cadmium)	-0.58	-0.55	0.01	Water below. Soil below.
Mn (Manganese)	0.046	1.45	0.4	Water below, Soil above.

3.5 Community-Reported Environmental Impacts

As depicted in Table 7, Community-based data corroborated the environmental assessments. Noise pollution (35.9%) was the most reported issue, attributed to persistent blasting, drilling, and truck movement. Dust emissions is next with 21.9%, presenting both respiratory health risks and reduced visibility. The findings from this result align with the stated objectives of Saka et al. (2025). Shocks or tremors were reported by 20.3% of respondents, reflecting the disruptive nature of quarry blasts. Vibration (14.1%), flying rocks (3.1%), and altered water taste (3.1%) further emphasized the community's vulnerability to both direct and indirect effects of quarrying. Building wall cracks (1.6%) highlighted cumulative structural damage, especially in areas with shallow foundations.

Table 7: Effect of Quarrying Activities on the Environment

Effects	Responses	
	Multiple responses	Percentage (%)
Dust	14	21.9
Noise	23	35.9
Shocks	13	20.3
Vibration	9	14.1
Flying rocks	2	3.1
Water taste	2	3.1
Cracking of walls	1	1.6
Total	64	100

Figure 4 presents a graphical summary of perceived environmental impacts associated with granite quarrying activities as reported by residents of the Magashanu community, while Figure 5 shows the effect of granite blasting on the wall of a building. The data, obtained through structured questionnaires and oral interviews, offer vital socio-environmental insights that complement the physical and chemical assessments presented earlier. The response distribution highlights a refined understanding of the direct and indirect effects of quarry operations on community well-being and the integrity of the surrounding ecosystem.

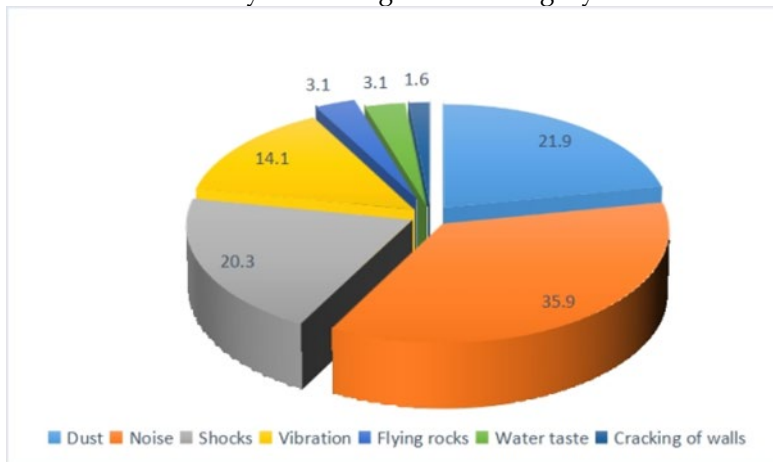


Figure 4: Effect of Quarrying Activities on the Environment by Residents of the Area



Figure 5: Cracked Wall in Magashanu Community due to Granite Quarrying

3.5.1 Dominant Environmental Nuisances

Noise pollution was the most frequently reported impact, by 35.9% of respondents. The observed prevalence of noise pollution aligns with the operational dynamics of granite quarrying, where processes such as drilling, blasting, rock crushing, and the movement of heavy-duty machinery consistently produce high-decibel sound levels. Extended exposure to such noise levels not only contributes to hearing impairment but also causes psychological stress, sleep disruption, and decreased productivity, especially in residential zones located within 500 meters of the quarry sites. These findings conform with those of some groups of researchers: Taiwo and Ogunbode (2024); Daramola and Imoukhuede (2014). The high prevalence of noise-related complaints underscores the inadequacy of existing noise-buffering or mitigation strategies by quarry operators. Non-compliance with WHO standards reflects weak enforcement and policy gaps, as critiqued by Oruonye and Ahmed (2020), Edo (2012), and Brown (2021) in resource management, while optimized extraction techniques (Mosch *et al.*, 2011) and waste recycling (Prochorov, 2023), which could provide technological solutions and reduce impacts, remain underutilized locally.

Dust emission followed as the second most reported concern, accounting for 21.9% of responses. These findings are consistent with environmental monitoring data and field observations, which revealed elevated concentrations of airborne particulates during dry weather conditions. Dust particles generated from blasting, excavation, and haulage are easily re-suspended in the atmosphere, increasing the risk of respiratory ailments such as asthma, bronchitis, and other pulmonary complications. Particularly concerning is the potential for airborne crystalline silica, as confirmed by high Si content in rock samples from both Datum and Tutu quarries, which poses long-term occupational and residential health hazards (Mankar *et al.*, 2019).

3.5.2 Perceived Physical Impacts and Safety Concerns

Ground shocks and vibrations, identified by 20.3% and 14.1% of respondents, respectively, are directly linked to the detonation of explosives used during rock fragmentation. These geodynamic disturbances often compromise the structural stability of nearby buildings, disturb the psychological well-being of residents, and have been associated with property depreciation. Although moderate in intensity, repeated shocks can initiate microfractures in walls and foundations, which, over time, may develop into wall cracking, as reported by 1.6% of respondents. This finding aligns with Kafu-Quvane and Mlaba (2024).

The low but significant incidence of flying rocks (3.1%) further emphasizes safety lapses during blasting operations. Fly rock incidents, although sporadic, represent acute hazards with the potential to cause injury, property damage, and fatalities, particularly where the designated blast exclusion zones are either poorly enforced or insufficiently delineated. This risk highlights the need for precision blasting technologies and stricter blast management protocols.

3.5.3 Water Quality Degradation as Perceived by Locals

Changes in water taste, as reported by 3.1% of residents, may indicate early signs of water quality degradation. While subtle, this perception resonates with laboratory results that revealed elevated concentrations of Fe, Mn, and Pb in water samples, surpassing WHO safe drinking water thresholds in some instances. Community sensitivity to changes in potable water, especially changes in taste and colour, often

serves as a proxy indicator for the onset of contamination, acting as an early warning system in environmental risk monitoring frameworks.

3.5.4 Holistic Evaluation and Contextual Significance

The collective perceptions reflected in Fig. 5 validate the instrumental role of community-based environmental monitoring in regions impacted by extractive industries. Beyond the technical data, these human-centred observations illustrate how environmental degradation manifests in tangible, everyday experiences. The prevalence of noise, dust, and ground disturbance complaints underscores a pressing need for mitigation interventions, particularly those focused on air quality control and blast-induced vibration management.

Moreover, the perceptual data bridges the gap between observed environmental metrics and community health impacts, reinforcing the importance of integrating participatory environmental governance into quarry operations. Quarrying companies operating in Magashanu and similar communities must recognize that environmental compliance is not limited to statutory benchmarks but also includes a social license to operate, which is anchored in transparent communication, impact minimization, and trust-building.

4.0 Conclusions

This study provides a comprehensive appraisal of the environmental and social implications of granite quarrying on the Magashanu community in Kaduna State, Nigeria. While the industry offers some economic benefits, particularly in terms of employment opportunities, these are substantially outweighed by the adverse environmental and public health consequences. Laboratory analyses revealed elevated concentrations of heavy metals, including lead (Pb), chromium (Cr), and iron (Fe), in both soil and water samples, often exceeding the World Health Organisation (WHO) permissible limits. Community-reported impacts, including dust and noise pollution, ground vibrations, deterioration of water quality, and structural damage, corroborated these findings.

The results underscore the inadequacy of existing environmental safeguards and the need for urgent, targeted interventions. Sustainable management of granite quarrying in Magashanu demands a paradigm shift from purely economic appraisals to a holistic, impact-driven framework. A comprehensive response to the identified environmental and social challenges should encompass: rigorous enforcement of environmental regulations, systematic monitoring of soil, water, and air quality, implementation of best practices in blasting techniques, dust control, and waste management, and inclusive stakeholder engagement that ensures community participation in the design and implementation of mitigation measures. Ultimately, mitigating the disproportionate burdens borne by quarry-host communities, such as Magashanu, requires not only technical and regulatory solutions but also a strong commitment to environmental justice and community well-being.

5.0 Recommendations

To effectively address the documented environmental and health impacts of granite quarrying on the Magashanu community, a community-centred and sustainable management framework is essential. Quarry operators should install real-time monitoring systems for dust, noise, and water quality, with data transparently reported to regulatory bodies. A Community-Quarry Liaison Committee (CQLC) should be established to give residents a formal role in environmental oversight and mitigation planning. Quarry permits must be tied to enforceable Environmental Management Plans (EMPs), including penalties for non-compliance and funds for progressive land rehabilitation. Finally, a quarry-funded environmental levy should support local capacity building to monitor and respond to quarry-related risks. These recommendations are grounded in the Magashanu experience and offer a practical roadmap for aligning extractive industry operations with environmental protection and community well-being.

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