



Assessment of Vibration and Noise Impacts of Drilling and Blasting Operations on Urban Structures: A Case Study of Zeberced Quarry, Abuja

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Abstract

This study assesses ground vibration and noise impacts from blasting operations at Zeberced Quarry, Abuja, on nearby urban structures within a 500–1000 m radius. Instrumental monitoring of eleven blast events recorded Peak Particle Velocity (PPV) using a portable seismograph and noise levels using a Class 1 precision sound level meter. Structural inspections were conducted on twenty buildings, complemented by a perception survey of thirty residents. Results show PPV values ranged from 2.50 mm/s at 500 m to 0.76 mm/s at 1000 m; significantly below the NESREA regulatory limit of 8 mm/s and USBM structural damage threshold of 50 mm/s, indicating minimal risk of direct structural failure. However, noise levels peaked at 68.20 dB(L) at 500 m, exceeding the NESREA daytime limit of 65 dB(L), though declining to 61.98 dB(L) at 1000 m. Resident surveys revealed 80% reported disturbance, including headaches, sleep disruption, and anxiety. The study concludes that while vibration-induced structural damage risk is low, noise pollution represents a critical environmental challenge requiring mitigation through acoustic barriers, controlled blasting schedules, and improved community notification systems.

Keywords: Blasting, vibration, noise pollution, Peak Particle Velocity, urban structures.

1.0 Introduction

Blasting is a fundamental unit operation in quarrying and open-pit mining, enabling efficient rock fragmentation for the extraction of construction aggregates [1]. However, the detonation of explosives releases substantial energy into the surrounding geological and atmospheric media in the form of ground vibrations and air blast noise, both of which propagate outward from the blast face and can adversely affect nearby structures and communities [2]. In urbanising regions like Abuja, Nigeria, the rapid outward expansion of residential settlements has progressively reduced the buffer distance between active quarry operations and civilian infrastructure, intensifying environmental and public health concerns [3,4].

Ground vibrations from blasting propagate through soil and rock formations as seismic waves, exerting dynamic stress on foundations, walls, and roofs. When vibration magnitude, quantified as Peak Particle Velocity (PPV), exceeds critical thresholds, progressive structural deterioration can occur. According to USBM RI 8507 guidelines, cosmetic damage to residential buildings can initiate at PPV levels of 12.5 mm/s, with significant structural damage occurring at or above 50 mm/s [5]. In Nigeria, the National Environmental (Quarrying and Blasting Operations) Regulations set a PPV limit of 8 mm/s for residential areas. Studies in both Nigerian and international contexts have documented PPV-related cracking in buildings within 500 m of active quarries, particularly those constructed with hollow block masonry or minimal structural reinforcement, which is prevalent in semi-formal Nigerian settlements [6,7,8].

Noise pollution from blasting presents a distinct but equally serious challenge. Explosive detonations generate intense air pressure waves that can peak above 120 dB(A) at the source, rapidly attenuating with distance but often exceeding safe levels in surrounding communities [1,9]. The World Health Organization [10] identifies prolonged exposure to environmental noise above 85 dB as hazardous, associating it with noise-induced hearing loss (NIHL), hypertension, cardiovascular disorders, sleep disturbance, and psychological stress. In Nigeria, the NESREA (National Environmental Standards and Regulations Enforcement Agency) (2009) prescribe a daytime limit of 65 dB for residential environments. However, studies in Abuja and Oyo State have documented blasting noise levels well above this threshold, with residents reporting widespread disturbances including anxiety, insomnia, and tinnitus [11,12,13].

Despite the existence of regulatory frameworks, including the Nigerian Minerals and Mining Act (2007) and Environmental Impact Assessment (EIA) Act (1992), enforcement remains inconsistent, and site-specific monitoring is often absent [14,15]. Abuja's Zeberced Quarry, located in Kubwa within the Federal Capital Territory (FCT), operates within 500–1000 m of densely populated settlements, including Byazin, Phase 4, Pipeline, and Gbazango. The quarry lies within the Precambrian Basement Complex of North-Central Nigeria, dominated by granite and migmatite formations [4]. Residents have reported structural cracks, sleep disruption,

and anxiety attributed to blasting, yet comprehensive empirical data quantifying vibration and noise impacts at this specific site are absent from the published literature, a gap that this study addresses directly.

This study assesses vibration and noise impacts from blasting operations at Zeberced Quarry on nearby urban structures and residents. The specific objectives are to: (i) measure and analyse PPV and noise levels at 50-metre intervals from 500 m to 1000 m from the blast face; (ii) evaluate the structural responses of twenty nearby buildings through visual inspection; (iii) document community perceptions through a structured survey of thirty residents; and (iv) recommend evidence-based mitigation strategies to promote sustainable quarry-community coexistence in Abuja's expanding urban landscape.

2.0 Methodology

2.1 Study Area

The study was conducted at Zeberced Quarry, a large-scale granite extraction operation located along Arab Road and Gbazango Extension in Kubwa, Bwari Area Council, Federal Capital Territory (FCT), Abuja (Latitude $9^{\circ}05' - 9^{\circ}15'$ N, Longitude $7^{\circ}10' - 7^{\circ}20'$ E). The quarry is situated within the Precambrian Basement Complex of North-Central Nigeria, characterised by granite and migmatite formations. Kubwa is one of Abuja's fastest-growing satellite towns, originally designated low-density residential but now experiencing rapid urban encroachment toward active industrial sites, making it an important focus for quarry-community impact research [4,15].

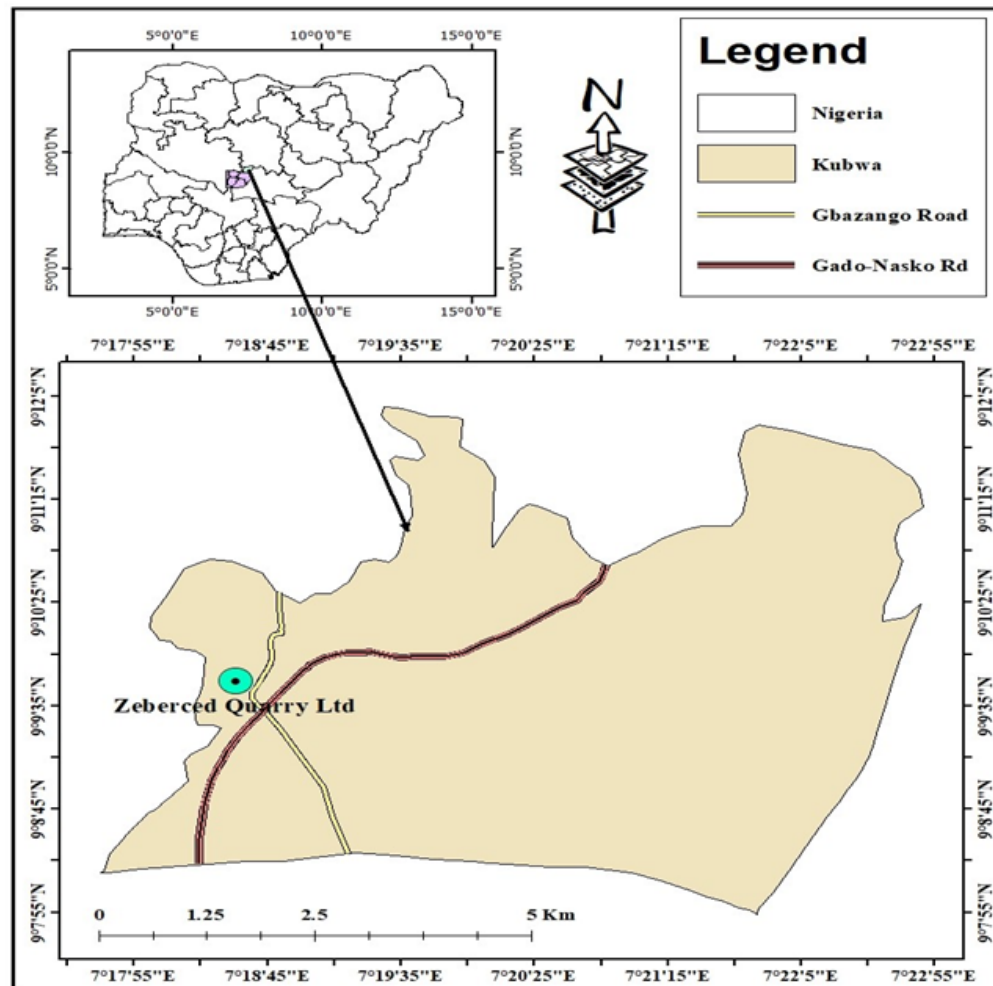


Figure 1: Map of Abuja showing Zeberced Quarry Limited

2.2 Instrumentation and Measurements

Instrumental monitoring was conducted during eleven scheduled blast events. Ground vibration was measured using a portable Minimate Pro seismograph, a purpose-built blast monitoring instrument capable of recording three-component PPV data. Noise levels were captured with a Class 1 precision sound level meter calibrated to IEC 61672 standards, recording peak noise in dB(L) during each blast. Both instruments were deployed simultaneously at eleven monitoring stations positioned at 50-metre intervals from 500 m to 1000 m from the blast face, enabling systematic assessment of the attenuation profile for both parameters. Blast details,

including detonation time, explosive charge configuration, and distance, were documented to support data interpretation [1,5,16].

2.3 Structural Inspection

Structural integrity assessments were performed on twenty buildings located within the 500–1000 m monitoring radius. Buildings were selected based on proximity to the blast face and diversity of construction type. Each structure was inspected using a standardised visual checklist documenting cracks (nature, orientation, and width), settlement, foundation movement, door and window frame misalignment, and ceiling defects. GPS data were used to correlate each building's location with corresponding PPV and noise measurements from the nearest monitoring station. Photographic documentation of observed damage was undertaken with occupant consent [7,8].

2.4 Community Perception Survey

A structured questionnaire was administered to thirty residents within the 500–1000 m impact zone, stratified across four age groups: 18–30, 31–45, 46–60, and 60+ years. The instrument captured demographic information, awareness of blasting operations, perceived intensity of vibration and noise, self-reported health effects (headaches, anxiety, sleep disruption, hearing discomfort), structural safety concerns, and satisfaction with quarry-community communication. Informed consent was obtained from all respondents. Survey data were analysed using descriptive statistics (frequencies and mean disturbance rates per age group) [17,18].

2.5 Data Analysis and Regulatory Benchmarking

Measured PPV and noise data were: (i) plotted against distance to characterise attenuation profiles; (ii) compared directly with the Nigerian NESREA regulatory PPV limit of 8 mm/s and the USBM RI 8507 structural damage threshold of 50 mm/s for vibration; and (iii) compared with the NESREA daytime noise limit of 65 dB(L) for noise. Triangulation of instrumental, structural, and perceptual data strengthened the validity of findings within this specific operational context. Ethical clearance was obtained from the Department of Mining Engineering, University of Jos, before data collection [5,14].

3.0 Results and Discussion

3.1 Ground Vibration Measurements

PPV values recorded during eleven blast events at distances from 500 m to 1000 m are presented in Table 1 and Figure 2. Values ranged from 2.50 mm/s at 500 m to 0.76 mm/s at 1000 m, exhibiting a consistent and progressive attenuation with increasing distance from the blast face.

Table 1: Ground vibration (PPV) measurements at Zeberced Quarry

S/No	Distance (m)	Measured PPV (mm/s)	NESREA Limit (mm/s)	Difference (mm/s)
1	500	2.50	8.00	5.50
2	550	2.21	8.00	5.79
3	600	1.92	8.00	6.08
4	650	1.75	8.00	6.25
5	700	1.53	8.00	6.47
6	750	1.41	8.00	6.59
7	800	1.30	8.00	6.70
8	850	1.22	8.00	6.78
9	900	1.01	8.00	6.99
10	950	0.95	8.00	7.05
11	1000	0.76	8.00	7.24

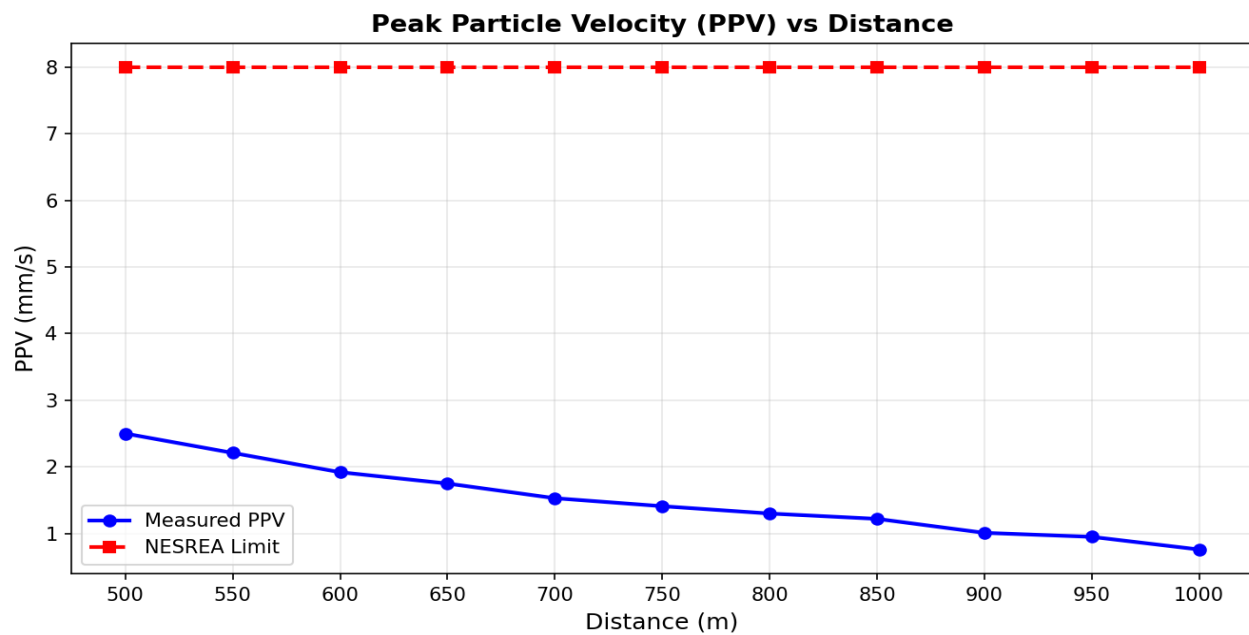


Figure 2: A plot of PPV (mm/s), against distance (m)

All recorded PPV values fell significantly below the NESREA regulatory limit of 8 mm/s and considerably below the USBM RI 8507 cosmetic damage threshold of 12.5 mm/s and the structural damage threshold of 50 mm/s [5,14]. The maximum recorded PPV of 2.50 mm/s at 500 m represents a safety margin of 5.50 mm/s against the regulatory limit. The consistent distance-decay pattern reflects established seismic wave propagation principles, whereby kinetic energy dissipates with distance due to a combination of geometric spreading and geological absorption by the basement complex materials [2,6].

These findings are broadly consistent with [1] and [16], who reported low-to-moderate PPV levels at comparable distances from Nigerian quarries in similar basement complex geological settings. Structural inspections of the twenty assessed buildings corroborated the instrumental data: only minor cosmetic cracks (surface-level, non-structural) were observed, none traceable with certainty to vibration-induced overstress. This is consistent with the observation that Nigerian informal-sector buildings, while generally more vulnerable than engineered structures due to hollow block construction and limited reinforcement [8,19], were not subjected to PPV levels approaching even the lower damage thresholds.

Nevertheless, the absence of structural damage at current vibration levels should not preclude ongoing monitoring. Structural degradation from blasting is often cumulative and progressive, commencing as microfractures that widen over successive events [7]. [8] documented precisely this pattern of incremental deterioration in residential buildings near Lokoja quarries, underscoring that current compliance does not eliminate long-term risk without sustained monitoring.

3.2 Noise Level Measurements

Noise levels recorded during the eleven blast events at distances from 500 m to 1000 m are presented in Table 2 and Figure 3. Values ranged from a peak of 68.20 dB(L) at 500 m to 61.98 dB(L) at 1000 m, exhibiting progressive attenuation with distance.

In contrast to the vibration results, noise levels revealed a more critical compliance picture. Measurements exceeded the NESREA residential daytime limit of 65 dB(L) at all distances up to and including 700 m (68.20 dB at 500 m to 65.08 dB at 700 m). Compliance was only achieved beyond 750 m, where the recorded level fell to 64.48 dB(L). This means that the entire near-field residential zone of Byazin, Phase 4, and Gbazango, situated within 500–700 m of the blast face, routinely experiences noise levels above the regulatory threshold during blasting events.

These findings align with the pattern documented by [11] at quarries near Mpape, Abuja, and by Umar and Oriri [12] in Oyo State, where blasting noise levels between 89 and 112 dB(A) were recorded well above NESREA limits, with limited regulatory response. The blasting noise generated at Zeberced Quarry, while considerably lower than these extremes, nonetheless presents a public health concern given Abuja's urban density. Low-frequency components of blasting airblast, as described by [11], penetrate residential structures more readily than high-frequency sounds, amplifying indoor noise perception and contributing disproportionately to the disturbance experienced by residents. [10] notes that even moderate but repeated noise events above 65 dB can disrupt sleep, elevate stress hormones such as cortisol, and contribute to cardiovascular strain over chronic exposure.

Table 2: Noise level measurements at Zeberced Quarry

S/N	Distance (m)	Measured Noise Level dB(L)	NESREA Standard dB(L)	Difference dB(L)
1	500	68.20	65.00	-3.20
2	550	67.17	65.00	-2.17
3	600	66.42	65.00	-1.42
4	650	65.72	65.00	-0.72
5	700	65.08	65.00	-0.08
6	750	64.48	65.00	+0.52
7	800	63.92	65.00	+1.08
8	850	63.39	65.00	+1.61
9	900	62.89	65.00	+2.11
10	950	62.48	65.00	+2.52
11	1000	61.98	65.00	+3.02

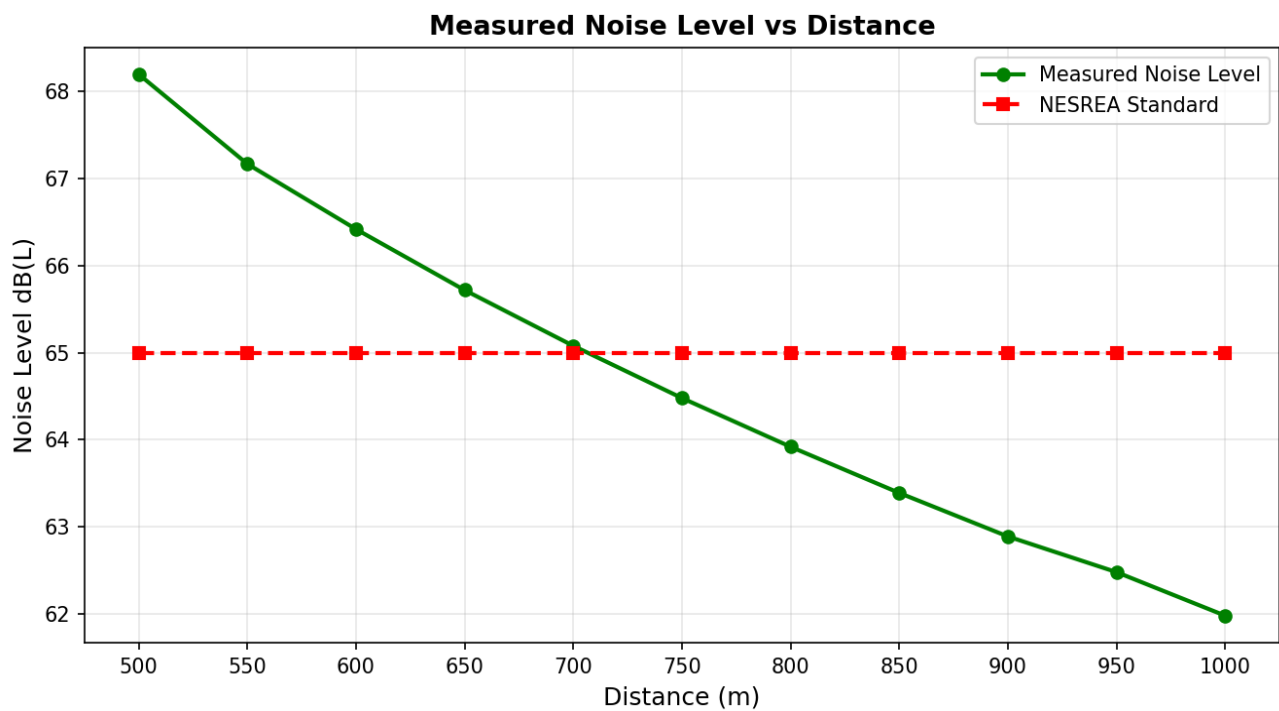


Figure 3: A plot of measured noise level (dB (L)) against distance (m)

3.3 Community Perception Survey Results

Survey responses from thirty residents stratified by age group are presented in Table 3 and Figure 4. Overall, 24 out of 30 respondents (80%) reported disturbance attributable to blasting operations.

Table 3: Community disturbance survey results by age group

S/N	Age Group	Disturbed	Undisturbed	Total	Mean Disturbance Rate
1	18–30	4	2	6	0.67
2	31–45	9	1	10	0.90

S/N	Age Group	Disturbed	Undisturbed	Total	Mean Disturbance Rate
3	46–60	7	1	8	0.88
4	60+	4	2	6	0.67
Total	–	24	6	30	0.80

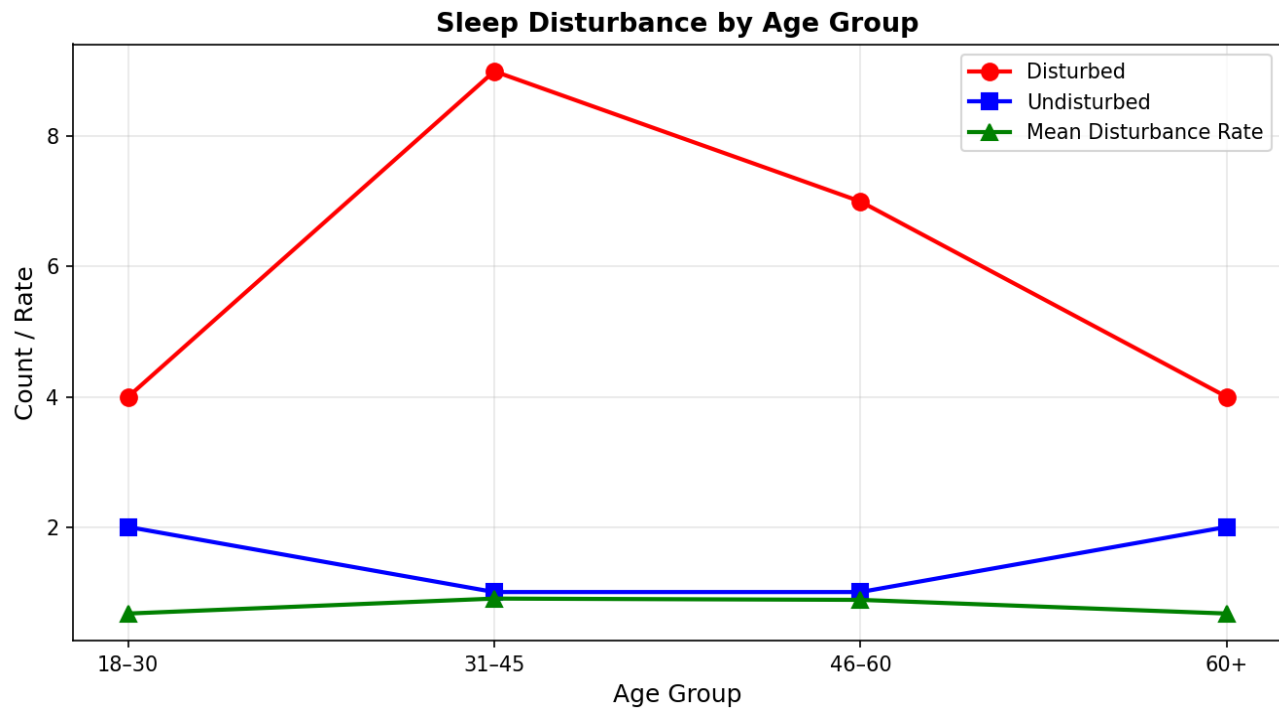


Figure 4: A plot of sleep disturbance by age group

The most frequently reported health complaints among disturbed respondents were headaches (65%), sleep disruption (53%), and anxiety (47%). Several respondents also reported startled reactions and hearing discomfort during blast events. Structural concerns were also raised, with a portion of respondents attributing observed wall and ceiling cracks to blasting, though instrumental and visual data suggest these are largely pre-existing or cosmetic.

The 80% overall disturbance rate confirms that blasting at Zeberced Quarry creates substantial community nuisance even where vibration and noise levels nominally approach or slightly exceed regulatory thresholds rather than dramatically surpass them. This finding illustrates a fundamental limitation of purely threshold-based compliance frameworks: noise bursts that are intermittent, sudden, and unpredictable produce a disproportionate psychological response compared to continuous noise at equivalent decibel levels [10,11].

The age-group distribution of disturbance is instructive. The 31–45 years cohort recorded the highest disturbance rate (0.90), consistent with the hypothesis that this group's active domestic and occupational schedules, including home-based work, child supervision, and routine sleep patterns, make them less tolerant of external disruption. The 46–60 years group followed at 0.88. Both younger adults (18–30, disturbance rate 0.67) and the elderly (60+, disturbance rate 0.67) showed relatively lower, though still substantial, sensitivity. Younger adults may demonstrate greater resilience or spend more time outdoors; elderly residents may have partially adapted to the disturbance or exhibit reduced sensory acuity, consistent with observations by [17] in comparable Ghanaian quarry communities.

The prevalence of headaches (65%) and sleep disruption (53%) aligns with documented physiological responses to blasting noise. [13] and [11] both identified similar symptom profiles in Nigerian communities near quarry sites, attributing them to noise-triggered cortisol and adrenaline stress responses. The anxiety rate (47%) further reflects the psychological burden of living in a zone of frequent and largely unannounced blasting events; a pattern associated with community unrest and declining quality of life documented by [17] in Ghana and [4] in Abuja.

The disconnect between measured vibration safety (PPV well below thresholds) and perceived community risk (high disturbance, structural concern) underscores a critical insight for quarry management and regulatory

policy: technical regulatory compliance alone does not guarantee social acceptance or community well-being. This finding has important implications for Nigeria's regulatory framework, which, as documented by [15] and [20], currently suffers from enforcement gaps, limited routine monitoring, and minimal community engagement requirements.

4.0 Conclusion

This study has provided empirical evidence on the vibration and noise impacts of blasting operations at Zeberced Quarry, Kubwa, Abuja, within the 500–1000 m impact corridor. The principal findings are as follows:

- (i) Ground vibration (PPV) measurements during eleven blast events ranged from 2.50 mm/s at 500 m to 0.76 mm/s at 1000 m. All values fell significantly below the NESREA regulatory limit of 8 mm/s and the USBM cosmetic damage threshold of 12.5 mm/s, indicating minimal risk of vibration-induced structural damage at current blast configurations. Visual inspections of twenty buildings confirmed this, revealing only minor cosmetic surface cracks.
- (ii) Noise levels peaked at 68.20 dB(L) at 500 m and exceeded the NESREA daytime limit of 65 dB(L) at all measurement stations up to 700 m. Regulatory compliance was achieved only beyond 750 m, directly implicating the densest residential zones surrounding the quarry.
- (iii) Community perception surveys revealed that 80% of residents (24/30) reported disturbance, with the 31–45 years age group most severely affected (disturbance rate 0.90). Headaches (65%), sleep disruption (53%), and anxiety (47%) were the most commonly reported health impacts, consistent with documented physiological and psychological responses to blast-induced noise pollution in Nigerian and international contexts.

The disconnect between measured vibration safety and perceived community distress confirms that regulatory compliance alone does not ensure community well-being or social acceptance of quarry operations. To achieve sustainable coexistence between Zeberced Quarry and surrounding communities, the following mitigation measures are recommended:

- (i) Blasting schedule control: Restrict blasting to a defined daytime window of 10:00–15:00 hours with a minimum of 24-hour advance notification to all communities within 1000 m, reducing night-time and early-morning disturbance.
- (ii) Acoustic barriers: Install solid acoustic barriers or dense vegetative buffers along the quarry perimeter facing Byazin, Phase 4, and Gbazango to attenuate airblast propagation toward residential zones.
- (iii) Precision blast design: Adopt reduced charge-per-delay configurations and optimised stemming to lower peak airblast pressure and PPV without compromising fragmentation efficiency, consistent with best practices from comparable operations in Ghana and South Africa [21-23].
- (iv) Quarry-community liaison committee: Establish a formal, transparent committee with community representation for ongoing grievance resolution, environmental reporting, and co-development of the blasting schedule.
- (v) Continuous monitoring programme: Deploy permanent or semi-permanent vibration and noise monitoring equipment to enable real-time compliance tracking and data-driven adaptive management of blast design parameters.

Future research should incorporate longitudinal structural monitoring to track cumulative crack propagation in affected buildings, and should extend survey methodology to include end-user building assessments by structural engineers. The development of Nigeria-specific PPV and noise thresholds that account for local construction methods and geological conditions remain a critical policy priority.

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