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Evaluating the Influence of Blast Design in Quarrying Operations on the Environment

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Abstract: *Blasting operations in quarrying have significant environmental impacts that must be managed carefully. Ground vibrations, air blasts, and dust generation are primary concerns. Understanding blast design parameters' impact on fragmentation efficiency and environmental consequences is essential for advancing quarrying practices. The primary challenge in quarrying is to balance these competing demands: achieving optimal rock fragmentation while minimising adverse environmental effects. This research aims to evaluate the influence of blast design on the environment by providing a detailed assessment of how different parameters affect productivity and environmental impact. This research investigates how various blast design parameters—specifically charge weight, blast pattern, timing sequences, and explosive types—impact the environment. The results show that none of the selected quarries complied with the regulated standard. However, factors that promoted low blasting vibration effects on the environment were bench height of not more than 10 m, very low charge load density of approximately 2 tonnes, and consistent application of non-electric detonators and connectors. Locations with a high bench height of 13.8 m recorded noise levels of 105 to 110 dB, fly rocks within 225 to 280 m, and a backbreak of 3.5 to 6.0 m, while locations with a bench height of 10 m and below recorded noise levels of 79 to 91 dB at 300 m away from the centre of the blast, while the backbreak and the fly rock distances are within 1.6–2.2 and 170-216, respectively. Siting a residential building over 1000 meters away from the quarry is significant for the control and reduction of vibration effects to a negligible degree. Therefore, the government should contract quality control monitoring to private companies for effective monitoring.*

***Keywords*:** Blast design, backbreak, ground vibrations, noise level, fly rock.

1. INTRODUCTION

Quarrying operations are central to the extraction of construction materials and minerals, with blasting being a fundamental technique for rock fragmentation. However, the effectiveness and safety of blasting operations are highly dependent on the optimization of blast design parameters, which include charge weight, blast pattern, timing sequences, and explosive types [1]. While effective fragmentation is crucial for operational efficiency and cost-effectiveness, it is equally important to address the associated environmental impacts, such as ground vibrations, air blasts, and dust generation. The primary challenge in quarrying is to balance these competing demands: achieving optimal rock fragmentation while minimizing adverse environmental effects [2]. Improperly designed blasts can lead to inefficient fragmentation, requiring additional processing and incurring higher costs [3]. Moreover, excessive ground vibrations and air blasts can cause structural damage, impact local communities, and result in regulatory non-compliance. Dust emissions from blasting further contribute to air pollution, affecting both environmental quality and public health [4].

Current practices in blast design often involve trial-and-error methods, leading to suboptimal results and potentially significant environmental consequences. Despite advancements in technology and modelling tools, many quarries still face difficulties in accurately predicting and controlling the outcomes of blasting operations [4]. There is a need for a comprehensive evaluation of how various blast design parameters impact both fragmentation efficiency and environmental sustainability. The problem is exacerbated by the increasing regulatory pressures and the growing demand for environmentally responsible mining practices. Quarry operators must not only optimize their processes for better fragmentation but also ensure compliance with environmental regulations and mitigate community concerns [5]. Thus, there is a critical need for research that systematically evaluates the influence of blast design parameters on both fragmentation efficiency and environmental impact.

The impact of blasting on the environment is a function of the quantity of explosives used. For a single hole, the quantity of explosives is determined by drilled-hole diameter and length, while spacing and burden determine the explosive distribution in multiple holes. All the blast parameters can cause increased ground vibration, air-blast (noise) and fly rock if they increase the charge density beyond the needed amount for fragmentation. Conditions that translate to increased ground vibrations include a larger drill-hole diameter, improper energy distribution due to inadequate spacing and burden, and higher benches. These conditions lead to increased charge density, which translates to high energy release per blast and results in higher ground vibration and air overpressure, increasing noise levels [6]. High charge densities release enormous energy, leading to excessive over-break and increasing the risk of fly rock. The potential risks of improper blast design with high benches and insufficient burden and excessive spacing should be a cause for caution and precision in your work, as they lead to poor confinement and uneven rock fragmentation, increasing the likelihood of fly rock during the blasting [7].

This research aims to evaluate the influence of blast design on the environmental by providing a detailed assessment of how different parameters affect productivity and environmental impact. The study seeks to offer actionable insights for optimizing blast designs in quarrying. This will ultimately contribute to more sustainable and cost-effective quarrying practices, aligning with both operational goals and environmental stewardship.

2. METHODOLOGY

2.1 The Study Area

The three (3) selected quarries, Samehase Nigeria (SNQ), Wada Mountain Investment (WMQ) and Mercury Mining Investment Limited (MMQ), are located in Ondo State, Nigeria. Samchase quarry is located in the outskirts of Ita-Ogbolu, a community in Akure North Local Government Area of Ondo State. The site is about 1.8 km away from Police Secondary School, Ita-Ogbolu and about 8km from Akure, the Ondo State capital. The quarry site falls within Latitude 7° 20° 45"N - 7° 21' 00"N and Longitude 5° 14° 30° - 5° 15' 00"E, covering 2 cadastral units of 0.4 km². The area is underlain by the Africa basement complex which is one of the well-known hard granitic compositions in the world. As classified by Owosusi *et al.* [8] the major rock types in the area are gneiss- migmitite-quartzite complex, schist belts which are low to medium grade supracrustal and meta-igneous rocks and Pan African granitoids (older granites). Other related rocks found within this basement complex include charnockitic, syenites and minor felsic and malfic intrusive. The area visibly exhibits a chain of granitic outcrops.

Woda Mountain Investment Limited quarry is located 1 km away from Alagbado village, a community that is 15 km from Ore, in Odigbo Local Government Area of the State. The quarry site is within Latitude 6° 46' 00" - 6° 46' 30"N and Longitude 4° 57' 30" - 4° 58"15"E. The Quarry Lease Area covers 5 cadastral units of 1.0 km². The area is dominated by the crystalline gneiss of the Basement complex which is exposed to both wet and dry seasons and the intense heat and relative humidity of the tropics. The geology of the area is predominantly that of basement complex which constitutes the oldest exposed rocks in Nigeria. Although they were regarded as Pre-Cambrian, the basement complex comprises the remnants of ancient sedimentary series, the met-sediments, which have been transformed into anatectic migmatites and granites. The met- sediment include quartzo-felspal biotite and homblende-gneiss, schist, quartzite, marbles and calc-silicate [9].

The geology and lithology of Mercury Mining quarry is similar to that of Woda Mountain Investment Limited quarry as both sites fall on same axis of Ondo State. There are two distinct geological domains in Ondo State: the areas underlain by the sedimentary rock in the south, and the areas also underlain by the pre- Cambrian Basement Complex rocks in the north and are mostly medium grain grey gneisses [10]. Mercury quarry is located at Ofosu, Idanre Local Government Area Council of Ondo State. The closest communities to the quarry are Elebisere and Ofosu. The Quarry Lease Area is bounded within Latitude 6° 46' 00" - 6° 46' 30"N and Longitude 5° 06' 45"E - 5° 07' 15"E. The lease area for the quarry covers 4 cadastral units of 0.8 km². Details about the geology of the study areas are presented in Figure 1.

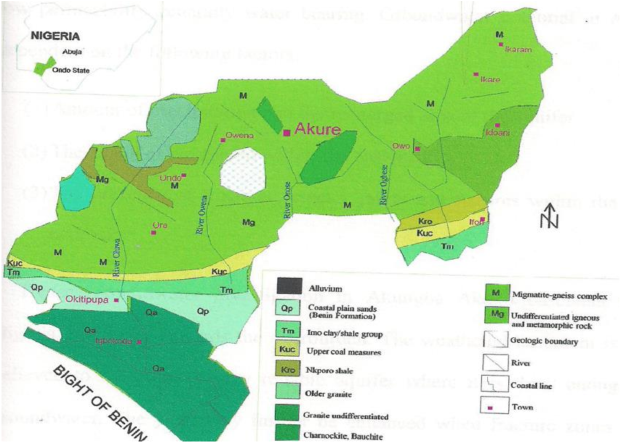

Figure 1: Geology of the study areas [11]

2.2 Data Gathering for Explosives and Bench Geometry

Five separate repeated visits were made to each of the three selected quarries for witnessing and assessment of their blasting procedures to obtain data for explosives used and bench geometry. During the visits, blasting parameters were ascertained; types of explosives used were identified with quantities confirmed, and other related information taken. The geometry of the blast holes including total number of blast holes, average depth and holes spacing and burden (S and B) were measured and ascertained in meters with the diameter in millimetres. Volume and tonnage of rock blasted was determined from the measured blasting parameters using Equation (1). The description of blast geometry is shown in Figure 2.

$$TON = TF \times n \times S \times B \times H \tag{1}$$

where TF is the tonnage factor, n is the number of drilled-hole, S is the spacing, B is the burden and H is the drilled-hole depth.

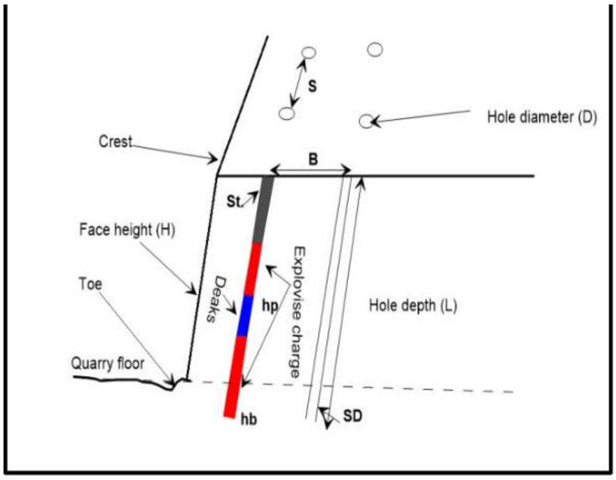

Figure 2: Typical bench in blasting operation

2.3 Determination of Rock Displacement and Back-break

Quarry pit was examined after each blast and the extent of back-breaks resulted was determined with measuring tape in meters, for several ones noticed around the crest of the quarry face. The average length of the back-breaks measured was recorded for the blast, and for analysis vis a vis explosives types and quantities applied and other blasting parameters. Likewise, the distance of throw of stone fragments' muck pile, from the centre of the muck pile to the quarry face, was also noticed and estimated with the aid of Global Positioning System, GPS, through navigation mode of the equipment.

2.4 Determination of Throw of Fly rocks

Fly rocks resulted from the blasts were keenly observed from a constant distance of 300 m away from each blasting point, and examined by the researcher. Special attention was paid to the ones causing damages such as puncture of roof top of nearby building. After blast, the distances of the few fly rocks discovered, or identified, were measured with the aid of Global Positioning System (GPS), described in Figure 3. Using the equipment's navigation mode at various locations, fly rocks were discovered after the initial careful viewing at 300 m away in the direction of blast throw. More attention was paid to the direction of throw in WMQ and MMQ, because it is directed to their crushing units. The average of the distances of the few fly rocks found away from the blast point was determined in meters and recorded for each blast. Data gathered were analysed based on their instantaneous charge density and blast-hole geometry.

2.5 Determination of Noise Intensity

The intensity of noise generated from each of the blasts was measured using noise meter shown in Figure 4, hung on a rig set up for the equipment. The noise level readings in decibel (dB) for each blast was taken at a constant distance of 300 m away from the blasting point and recorded accordingly. The 300 m used is the minimum permissible distance limit for flaggers and other personnel (not involved in actual blast) according to National Environmental Standards and Regulations Enforcement Agency (NESREA) Standards; Schedule VI, Sec. IV(e) of the Regulation [12]. From the blasts readings from each of the quarries assessed, the average noise level was also determined, keeping in mind that the USBM 134 dB.

Figure 3: Global positioning system, GPS

Figure 4: Noise meter (sound level meter)

2.6 Measurement of Structural Damages

Visual inspection, measurement of cracks with measuring tape and photograph taking of the affected nearly buildings within the neighbourhood of the quarries and interactive survey with the residents of the host communities were carried out to determine the structural damage to buildings as a result of the blasting operations.

Requests were made from the complainants to confirm their claims of damage done to structures, either due to ground vibration or fly rocks, resulting from the blasts. The NESREA standard for permissible distance limit between residences and quarry location is applied in analysing structural damage. Photograph pictures of damages done to properties like cracks on walls, puncture of roof tops, ceilings falling-off, etc. were also taken.

3. RESULTS AND DISCUSSION

3.1 Blast Geometry and Energy

The report of the blast geometries and the explosive quantities used in the selected locations are in Table 1. The results show that SNQ employed blast design techniques inconsistent with the recommended standard, with an average bench height of 13.8 m against the maximum permissible limit of 10 m. Likewise, WMQ employed a high bench height of 18 m on average. These are clear violations of bench height standards. Another anomaly is the occasional higher charge load density (CLD) of up to 11.1 tons, above the maximum limit of 10 tons per blast round. More so, excessive spacing and burden of 2.5 by 2.5 m against 1.5 by 1.5 m. The results of MMQ indicated that the blast design has an average bench height of 10 m for the five blasts evaluated. It shows that the design is within the NESREA maximum allowable limit of 8-10 m. Consequently, a very low charge load density (CLD) of an approximated value of 2 tons was recorded within the allowable limit (10 tons per blast round).

The general implication of high drilled-hole depth in blast design is that it increases explosive consumption per blast round [13] and increases the volume of energy dissipating into the environment at a time. Researchers have found that although this practice increases production, it may result in more environmental damage [14]. On a deposit with high discontinuity, little energy goes into fragmentation proper, while a large volume of energy dissipates into the environment, causing increased disturbances [15]. Operating within the allowable limits may lead to the optimization of operations and reduced costs incurred. Caution is also needed for operations far below the requirement as it may result in boulders production and increase secondary blasting. Blasting quarry operations can severely impact surrounding communities, especially when established safety and environmental limits are violated. Excessive noise from air overpressure disrupts daily life, causing stress, sleep disturbances, and hearing damage over time [16]. Ground vibrations from blasting can damage nearby structures by creating cracks in buildings and infrastructure. At the same time, fly rock poses significant safety risks because it can cause damage to properties, injuries to people, or fatalities if poorly controlled. These impacts erode public trust, generate community complaints, and may lead to legal and regulatory actions. Prolonged exposure to such disturbances can diminish the quality of life and harm community well-being.

Table 1: Bench geometry data and blast energy consumption for the quarries

Blast	H_{NO}	H_d (m)	S (m)	B (m)	HD (mm)	S_t (m)	Q_T (Ton)
SNQ1	60	18	2.5	2.5	76	1.5	2.70
SNQ2	50	8	2.7	2.7	76	1.0	1.00
SNQ3	75	16	2.7	2.7	76	1.5	4.65
SNQ4	45	12	2.5	2.5	76	1.5	1.73
SNQ5	50	15	2.5	2.5	76	1.5	2.85
WMQ1	98	18	2.5	2.5	125	1.4	9.80
WMQ2	80	18	2.5	2.5	125	1.4	8.25
WMQ3	90	18	2.5	2.5	125	1.4	8.25
WMQ4	1	18	2.5	2.5	125	1.4	7.08
WMQ5	112	18	2.5	2.5	125	1.4	11.10
MMQ1	40	10	2.5	3.0	125	1.8	1.64
MMQ2	40	10	3.0	3.0	125	1.8	1.64
MMQ3	50	10	3.0	3.0	125	1.8	2.05
MMQ4	40	10	3.0	3.0	125	1.8	1.64.
MMQ5	50	10	3.0	3.0	125	1.8	2.10

H_{NO} is the number of hole, H_d is the drilled-hole diameter, S is the stemming, B is the burden, HD is the drilled-hole diameter, S_t is the stemming and Q_T is the quantity of explosive.

3.2 Explosives Ration and Blasting Accessories

The explosive selection in blasting operation depends on many factors, including the water condition of the drilled hole, as it causes explosive deterioration. Suppose the drilled-hole experiences minor water seepage; packed slurry, emulsion and nitroglycerin-based explosives are used for a primer charge, while the column charger is Ammonium Nitrate and Fuel Oil (ANFO). If the water seepage is high, ANFO may not be used because ammonium nitrate deteriorates quickly when in contact with water [17]. However, in a dry-drilled hole, any explosive can be used. Blasting accessories are used to design detonation to achieve effective fragmentation with little impact on the environment.

The findings on the use of blasting accessories in the study locations are in Table 2. The results show that while

MMQ consistently used non-electric (NONEL) connectors and detonators, which are environmentally friendly blasting accessories, SNQ did not employ them. Also, WMQ were inconsistent with using NONEL detonators and connectors. The findings also reveal that none of the assessed quarries uses relay delay, an essential blasting accessory for reducing the impact of ground vibrations and air blasts. The relay delay permits the sequential detonation of explosives in a blasting round to reduce the impact of the simultaneous detonation of a vast mass of explosives [18]. These can be considered poor blasting material selection and violate environmental standards. These accessories are required to comfort the residents within the 1,000 m range of the quarry despite having residential structures within 500 m from the centre of the blast.

Table 2: Explosives and blasting accessories for the quarries

Blast	High Xplo (kg)	ANFO (kg)	Plain. Det. (pcs)	Cordtex Fuse (m)	Det. (pcs)	Conn. (pcs)	Relay (pcs)
SNQ1	900	1,800	1	1,000	Nil	Nil	Nil
SNQ2	1,000	Nil	1	700	Nil	Nil	Nil
SNQ3	900	3,750	1	1,500	Nil	Nil	Nil
SNQ4	600	1,125	1	600	Nil	Nil	Nil
SNQ5	600	2,250	1	1,300	Nil	Nil	Nil
WMQ1	2,450	7,350	7	3,200	Nil	Nil	Nil
WMQ2	1,900	6,350	1	Nil	80	80	Nil
WMQ3	3,750	4,500	7	2,900	Nil	Nil	Nil
WMQ4	4,575	2,500	7	3,500	Nil	Nil	Nil
WMQ5	3,100	8,000	1	Nil	112	112	Nil
MMQ1	560.0	1,081.6	2	Nil	40	40	Nil
MMQ2	535.0	1,100	2	Nil	40	40	Nil
MMQ3	700.0	1,352	2	Nil	50	50	Nil
MMQ4	572.5	1,071.1	2	Nil	40	40	Nil
MMQ5	720.0	1,382	2	Nil	50	50	Nil

3.3 Environmental Impact Resulting from the Blast Design

The environmental impacts of the blast design and the blast accessories used are presented in Table 3. The impact evaluated includes the noise level at 300 m away from the centre of the blast, back break, fly rock and the impact of vibrations on residential structures within 1000 m range of the centre of the blast. SNQ recorded noise levels ranging from 105 to 110 dB, fly rocks are within 225 to 280 m and back-break of 3.5 to 6.0 m. These values exceeded the maximum allowable limit of 114 dB and 300 m for noise level and fly rock, respectively. The fly rock values could be considered dangerous for the blaster men positioned within 200 m and risky for the flaggers and other personnel not involved in the blast. The poor blast design in the quarry is evident in the high back-break and high degree of ground vibration that impacts the nearby structures, including buildings in far locations up to 1,000 m from the quarry site. The impact of high back-break is evident as several hanging walls can be seen in the quarry.

Results from WMQ show that noise level is within 88 to 92 dB, fly rock distance ranges from 180 to 240 m, and back-break values range from 2.0 m to 5.0 m. The fly-rock values signal high hazard for blaster men and flaggers. Although the back-break reading is high, the noise level and the fly-rock distance are within the maximum allowable limits. These findings imply that the quarry does not pose more danger to their immediate environment, but their design will produce a rough free face. Since WMQ uses a 2.5 m burden and back-break ranges from 2 to 5 m, they will be experiencing poor drilling within the first two rows. The result will be falling of hanging walls, unstable walls, and poor fragmentation with increasing boulders [19]. The poor fragmentation will consequently result in several secondary blasting, which are known to increase the total cost of a mining operation. Therefore, caution is necessary regarding the blast design in the WMQ (especially on blasts WMQ1 and WMQ5) to reduce back-breaks and the impact of vibration on structures.

The results for MMQ indicated that the noise level is from 79 to 91 dB, while the back-break and the fly rock distances are within 1.6 – 2.2 and 170 – 216, respectively. These values fall within the acceptable limits. Hence, it is less worrisome to the environment, as the back-break is fairly manageable with less difficulty in drilling operations towards the affected parts of the crest of the bench. A good blast design is evident in the impact of vibration on structures within 1,000 m of the blasting centre, which has a low rating. However, no house was within a 1,000 m radius of the blast centre. This factor of isolation of the quarry far away from host communities made blasting vibration effects less pronounced as the results of the assessment survey of the buildings. Conclusively, quarry MMQ's positive and satisfactory performance in terms of compliance with NESREA standards regarding the five blasting operations studied and reported, except for the spacing and burden, which require adjustments to attain total compliance.

Table 3: Environmental effects of various blast designs for each blasting

Blast No.	**Noise (dB)**	**Backbreak**	**Fly rock (m)**	**Vibration**
SNQ1	105	5.2	225	High
SNQ2	106	3.5	250	High
SNQ3	110	6.0	280	Medium
SNQ4	106	4.5	230	High
SNQ5	108	5.8	265	High
WMQ1	91	5.0	240	High
WMQ2	89	2.0	180	Medium
WMQ3	90	4.7	220	Medium
WMQ4	88	3.2	220	Medium
WMQ5	92	2.0	190	High
MMQ1	82	2.0	180	Low
MMQ2	85	1.6	193	Low
MMQ3	88	2.0	206	Low
MMQ4	79	1.8	170	Low
MMQ5	91	2.2	216	Low

Table 4 compares the evaluated environmental impacts of blasting in the selected locations with the maximum allowable limits recommended by NESREA. Table 5 also summarises the degree of vibration from the quarries compared to the maximum allowable limits. The unsatisfying blasting effect on the quarry's environment was not unconnected with standards violations. These include more extended spacing and burden of up to 2.7 and 2.7 m, against 1.5 and 1.5 m maximum allowable limits for spacing and burden, respectively. Likewise, the blast-hole depth and bench height of up to 16 m and 18 m exceeded the maximum permissible bench height of 10 m. In addition, even though the explosives' charge load density (CLD) did not exceed the maximum allowable limit of 10 tons per blast in any of the five blasts studied in SNQ, non-usage of more environment-friendly blasting accessories such as non-electric (NONEL) detonators, connectors and relay delay, could be regarded as another factor responsible for discomfort complaints from host community residents and likewise the high degree of damaging impacts of blasting vibration on their nearby structures to the quarry.

Factors that promoted low blasting vibration effects on the environment of quarry MMQ include a moderate average bench height of 10 m for the five blasts, which meets with the NESREA allowable limit of 8-10 m maximum. In addition, the very low charge load density (CLD) of an approximated value of 2 tons, far below the maximum limit of 10 tons per blast round, made the vibration impacts minimal and satisfactory. Finally, consistent application of non-electric (NONEL) detonators and connectors for blasts at the quarry, despite its location at over 1000 meters away from the residential area, is significant for the control and reduction of vibration effects to the barest minimum of low to negligible degree attained at quarry MMQ.

Table 4: Summary of results compared with NESREA standards

S/N	**Environmental Effects**	**Standard**	**SNQ**	**WMQ**	**MMQ**
1	Air Blast (Noise) Level (dB)	≤ 114	107	90	85
2	Fly Rock (m)	≤ 200	250	210	193
3	Bench Height (m)	8-10 Max.	13.8	18.0	10m
4	Spacing and Burden (m)	≤1.5 & 1.5	2.5 & 2.5	2.5 & 2.5	3.0 & 3.0)
5	Charge Loading Density (tons)	≤10	1	7.08	1.64
6	Quarry to residences (m)	≥ 1,000	≥ 500 m	≥ 500 m	≥ 1,000 m
7	Vibration Impact Degree	V. low to Low	High	Medium	Low
8	Flaggers and personnel position (m)	≥ 300	Above 300	Above 300	Above 300
9	Blaster and Blasting Crew (m)	≥ 200	≥ 300	200-250	250-300

Table 5: Summary of degree of vibration effects on structures

Quarries	Residents' comments at varying Distances		
	≤ 500 m	500 m – 1000 m	1,000 m -1,500 m
SNQ	H	H	H
WMQ	H	M	L
MMQ	N	L	L

Note: Very Low or Negligible (N), Low (L), Medium (M) and High [20].

4. CONCLUSIONS

The study was able to establish the effects of controllable parameters on the environmental rock-blasting disturbances experienced within the communities of the study area. Data on bench geometry and explosives have been established from primary sources as the blasts from each of the analysed quarries were witnessed and assessed. Based on the data acquired, the results showed positive and satisfactory performance by Mercury Mining Investment Limited quarry (Quarry MMQ) in terms of compliance with NESREA standards for control of rock blasting operation. The satisfactory remark is evident in the recorded low noise level (85 dB), shorter fly rock throw range (193 m), minimal back-break (2 m average) and low (L) to the negligible degree of blasting vibration impact on near buildings. However, the results also clearly indicated many deficiencies and non-compliance with environmental standards on the part of two other quarries, namely, Samchase Nigeria Limited quarry (SNQ) and Woda Mountain Nigeria Limited quarry (Quarry WMQ). Results values for both quarries revealed violations of controllable parameters limits, namely, bench height of 13.8 m average and 18.0 m average at Quarry SNQ and WMQ, respectively, against the permissible limit of 10 m NESREA standard. The Spacing and Burden of (2.5 by 2.5) m being used at both quarries exceeded the maximum allowable limit of (1.5 by 1.5) m. Likewise, the explosives charge load density (CLD) of 10 tons maximum limit was occasionally exceeded by Quarry WMQ, while both quarries equally violated the 1,000 m minimum distance limitation from quarry to residential areas as human dwellings exist within 500 - 1,000 m distance radius to the quarries. These anomalies contributed to medium (M) to high (H) degrees of negative impacts of blasting vibration emanating from the quarry blasts on the surrounding buildings, as observed. In order to curtail the environmental disturbances and alleviate the plights of the affected communities, the study advocated mandatory regular submission of quarterly environmental monitoring reports (EMR), which should be under the supervision of a quality control officer (consultant) for the three quarries studied. It is essential to constantly reveal environmental issues connected with their operations and provide mitigating measures to attain environmental sustainability in the host communities. Mitigating environmental disturbances resulting from quarry blasting requires strict compliance with NESREA standards and Industry regulations. Using improved blast design, such as controlling a burden, spacing, and charge density, lowers the noise, vibration and fly rock. Precision and impact minimisation is facilitated by controlled blasting techniques such as pre-splitting and electronic detonators. Audible ground and air overpressure alarms that may alert contractors of non-compliant operations or, in the event of an imminent failure on a site, ensure they are alerted proactively. Continued community involvement builds trust and identifies and addresses concerns continuously. In addition, incorporating barriers or buffer zones onto the site to protect nearby buildings and population centres is a prudent decision demonstrating a commitment to operational efficiency without sacrificing environmental conscience. Advanced rock-breaking methods, using chemical agents and modern machinery, offer efficient alternatives to traditional blasting. These techniques can protect communities and the environment while ensuring precise, efficient quarrying operations with reduced noise level, vibration, and fly rock. Investing in these innovations promotes sustainability and aligns with evolving regulatory and societal expectations.

REFERENCES

[1] Adesida, P. A. (2023). A rock engineering system approach to estimation of blast induced peak particle velocity. *International Journal of Mining and Geo-Engineering*, 57(1), 101-109. https://doi.org/10.22059/ijmge.2022.343687.594973

[2] Taiwo, B. O., Gebretsadik, A., Abbas, H. H., Khishe, M., Fissha, Y., Kahraman, E., Rabbani, A., Akinlabi, A. A. (2024). Explosive utilization efficiency enhancement: An application of machine learning for powder factor prediction using critical rock characteristics. *Heliyon*, 10(12), e33099. https://doi.org/10.1016/j.heliyon.2024.e33099

[3] Nikkhah, A., Vakylabad, A. B., Hassanzadeh, A., Niedoba, T. and Surowiak, A. (2022). An Evaluation on the Impact of Ore Fragmented by Blasting on Mining Performance. *Minerals*, 12(2):258. https://doi.org/10.3390/min12020258

[4] Owolabi, A. O. and Adesida, P. A. (2020). The Environmental and Health Implications of Quarrying Activities in the Host Community of Oba-Ile in Akure, Nigeria. *Journal of Human Environment and Health Promotion*, 6 (1), 6-10. https://doi.org/10.29252/jhehp.6.1.2

[5] Kinyua, E.M., Jianhua, Z., Kasomo, R. M., Mauti, D., Mwangangi, J. (2022). A review of the influence of blast fragmentation on downstream processing of metal ores. *Minerals Engineering*, 186. 107743. https://doi.org/10.1016/j.mineng.2022.107743

[6] Lopes, G. S., Vinueza, G., Trzaskos, B., Ribeiro, A. F. and Araujo, R. G. (2022). Correlating blast vibrations and geomechanical properties to determine damage profiles and improve wall conditions in open pit mining. Anais da Academia Brasileira de Ciências: Engineering Sciences, 94(4), e20211080.

[7] Mishra, A. K. and Rout, M. (2011). Fly rocks – Detection and Mitigation at Construction Site in Blasting Operation. World Environment, 1(1), 1-5.

[8] Owosusi, O. O., Adekoya, J. A. and Adisa, A. L. (2019). Mineralization potential assessment of stream sediment geochemical data using R-mode factor analysis in Nigeria. *Journal of Emerging Trends in Engineering and Applied Sciences*, 10(2), 54-60. https://hdl.handle.net/10520/EJC-178ff32b40.

[9] Ogunsanwo, F. O., Olowofela, J. A., Okeyode, I. C., Idowu, O. A. and Olurin, O. T. (2019). Aeroradiospectrometry in the spatial formation characterization of Ogun State, south-western, Nigeria [online]. *Scientific African*, 6. Available at: https://doi.org/10.1016/j.sciaf.2019.e00204 (Assessed: 1 September, 2024).

[10] Elueze, A. A. (2000). Compositional appraisal and petrotectonic significance of the Imelu banded ferruginous rock in the Ilesha schist belt, southwestern Nigeria. J. Min. Geol., 36(1), pp.8-18.

[11] Okpoli, C.C. (2013). Borehole Logs and Physico-chemical Investigation of Some Presumptive

Springs in Akoko, South-western Nigeria. *Environmental Research Engineering and Management,* 65(3), 40-48. https://doi.org/10.5755/j01.erem.63.3.4351.

[12] National Environmental Standards and Regulations Enforcement Agency (2013). *National Environmental (Quarrying and Blasting) Regulations*. Available from: Quarrying_and__Blasting_Operations.pdf (Accessed: 20 October, 2024).

[13] Oates, T. E. and Spiteri, W. (2021). Stemming and best practice in the mining industry: A literature review. *Journal of the Southern African Institute of Mining and Metallurgy,* 121(8), 415–426. http://dx.doi.org/10.17159/2411-9717/1606/2021.

[14] Zhao, T., Crosta, G. B. and Liu, Y. (2022). Analysis of slope fracturing under transient earthquake loading by random discrete element method. *International Journal of Rock Mechanics and Mining Sciences,* 157, 105171. https://doi.org/10.1016/j.ijrmms.2022.105171.

[15] Jang, H., Handel, D., Ko, Y., Yang, H. S. and Miedecke, J. (2018). Effects of water deck on rock blasting performance. *International Journal of Rock Mechanics and Mining Sciences*, 112, 77–83. https://doi.org/10.1016/j.ijrmms.2018.09.006.

[16] Kumar, A., Prasad, S. and Reddy, R. S. (2024). Environmental implications on blasting operations in Indian quarry mines. International Journal of Mining and Geo-Engineering, 58(3), 289-294. https://doi.org/10.22059/ijmge.2024.355043.595034.

[17] Xie, Q., Dai, H., Qin, X., Zhang, Z., Huang, X. and Ouyang, D. (2024). A method for controlling the blasting effect of reinforced concrete columns. *Results in Engineering,* 102068. https://doi.org/10.1016/j.rineng.2024.102068.

[18] Monjezi, M. and Dehghani, H. (2008). Evaluation of effect of blasting pattern parameters on back break using neural networks. *International Journal of Rock Mechanics and Mining Sciences,* 45(8), 1446–1453. https://doi.org/10.1016/j.ijrmms.2008.02.007.

[19] Singh, N., Tiwari, R. and Prasad, V. (2019). Effective dust suppression techniques in quarrying. *Journal of Environmental Health Science,* 43(7), 415-426.

[20] Zorzal, C. B., Nogueira, C. de L. and Lima, H. M. de. (2022). Blast-induced ground vibrations: a dynamic analysis by FEM. *Research, Society and Development,* 11(13), e205111335421. https://doi.org/10.33448/rsd-v11i13.35421.