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Enhancing Mine Safety: An Assessment of Particulate Dust and Noise at Kristal Vountein Quarry, Nigeria

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Abstract

Enhanced productivity in mining operations has led to rising mechanisation of the production process, which consequently increases the quantity of dust and noise generated. Dust-related health risk to mine workers is a function of size, concentration and total time to which they were exposed to it. Hearing challenges that are often stimulated by noise depend on the sound's rate of recurrence levels of pressure and workers' exposure. Contact with sound pressures and dust concentrations beyond the threshold limits prescribed range by statutory environmental protection bodies may have a damaging consequence on the health of mine workers. This study therefore assessed quarry dust concentration and noise level in Kristal Vountein Quarry vis-à-vis prescribed standards and proposed appropriate control measures to minimise this menace. The noise levels are generally below the danger limit of 90 dB, with the maximum noise level of 85.8±2.6 dB obtained from the crushing point. The findings revealed that the air quality index (AQI) near the processing crusher varied with distance. At 50 m, PM10 and PM2.5 levels were 197.4±11.3 and 215.1±11.3, indicating unhealthy and very unhealthy exposures, respectively. At 100 m, the AQI were 164.4±10.1 and 189.3±9.5, signalling unhealthy conditions. Further distances showed decreasing AQI, with 150 m indicating unhealthy for sensitive groups, 200 m is moderate for PM10, and 250 m is moderate for PM10 and unhealthy for sensitive groups for PM2.5. Therefore, quarry workers, especially in the crushing area, should always put on their protective equipment to protect them from the hazardous environment.

Keywords

Blasting, Mineral sector, Noise assessment, Safety

1. Introduction

Industrial rocks, containing minerals such as granite, limestone, gypsum, and quartz, are critical to the economy (Kolala and Dokowe, 2021). Taiwo and Omotehinse (2022) observed that industrial rocks such as marble and dolomite are important raw materials for paints, animal feed, construction, manufacturing, and infrastructure development. They further stated that the extraction and processing of these generate jobs, stimulate economic growth, and contribute considerably to numerous industries, thus promoting economic stability. Rock quarrying is the process of removing rock and minerals by mechanically extracting them from the deposits (Taiwo et al., 2024; Quinta-Ferreira, et al., 2023). According to Quinta-Ferreira et al. (2023) quarrying has been practised for thousands of years, with evidence reaching back to antiquity. The significance of rock quarrying stems from its numerous applications and uses in construction, infrastructure development, and manufacturing industries (Onifade et al., 2023). Furthermore, rock quarrying has a significant impact on environmental sustainability. Quarried sites can be carefully managed and rehabilitated to reduce their influence on ecosystems and restore the landscape (Lameed and Ayodele, 2010). This involves implementing best practices in dust control, noise reduction, and water management. However, Adepitan et al., (2018) reported that quarrying causes a variety of environmental issues, including ground vibrations, pollution of air with the generation of large quantities of dust, as well as noise pollution. Quarry dust, a by-product of rock blasting and crushing operations, is known to negatively impact the environment and consequently impair human health (Rav et al., 2020). Studies have shown that long-term exposure to quarry dust can cause respiratory problems such as asthma and lung infections (Rajanayagam, et al., 2023; Pandey et al., 2023). Sen et al., (2016) also stated when inhaled crystalline silica dusts accumulate in human lungs, they increase the risk factor for respiratory and pulmonary diseases such as silicosis, pneumonia, bronchitis, tuberculosis and cancer of the lung. Furthermore, Pandey et al. (2023) stated that the presence of quarry dust in water bodies can disrupt aquatic life and alter ecosystem dynamics. As a result, industries must take appropriate steps to reduce the effects of quarry dust on the environment. Owolabi (2022) observed that dust-related health problems are common in underdeveloped nations such as Nigeria. Granite quarrying in Nigeria delivers significant economic benefits by creating jobs, promoting infrastructure development, and contributing to the country's GDP (Taiwo et al., 2024; Eyre, 2007). Granite quarrying has been identified as a human activity that causes pollution in the environment. The sector also benefits local economies because granite is a key building material, contributing to housing and infrastructure projects that fuel economic growth and raise living standards. The significant level of noise and particles created in the drilling and crushing sites classifies them as hazard zones (Sarkar, 2023). Furthermore, quarry workers' exposure to this pollution, combined with their general lack of use of protective equipment, predisposes them to a variety of audiometric and respiratory ailments that are common among residents living near quarry sites. Research into granite dust sensitization in Nigeria is critical for identifying health risks, creating preventative measures, and enhancing occupational safety in the granite mining and processing industries. This study so analyzed noise generation and particulate dust emission to educate the quarry sector on the best dust and noise control measures, ultimately improving Nigerian granite quarry safety. It is also intended to encourage the government to develop policies that will assist protect workers and the host

Quarry dust is a by-product formed from the brokerage of boulders when they undergo crushing or grinding processes. The constituents of quarry dust depend on the boulders' source and the soil's composition (Peng et al., 2016). These dusts are often composed of minerals such as phosphates, carbonates, silicate, quartz, feldspars and sulphates. These dusts cause diseases allowed into the environment, making the mine environment toxic for workers and the immediate communities. The classification of mine dust is based on the particulates' size distribution as well as their physiological consequences (Liu and Liu, 2020). Mine dust can be classified as toxic, carcinogenic (cancer-causing), fibrogenic (silicosis-causing), explosive and nuisance in terms of their physiological effects (Paluchamy, et al., 2021). In terms of their particle sizes, they are classified as coarse particles (>20 µm), fines (20–1 µm) and ultra-fines (<1 µm) (Lin et al., 2005).

Noise, which is an undesired sound, consists of three components that are linked to one another, they are the source, receiver and transmission medium (Pramendra and Vartika, 2011). Sound often travels through the atmosphere and the structural materials of any building accommodating the receiver (Attenborough, 2014). Noise often comes with undesirable low or high, which causes hearing disturbances and interest or habit of the receiver and that ambient condition distinguishes it from sound (Adesida and Afu, 2018). It is influenced by the sound generated during that specific period. Noise, like sound, is measured in decibels (dB). The lowest sound level that people with exceptional hearing can identify is about 20 dB, whereas the highest sound commonly encountered is that of a jet aircraft, which is roughly 170 dB (Garg, 2022). According to Lee et al., the effects of noise exposure on people vary depending on exposure time, sound intensity, and individual sensitivity (Lee et al., 2023). These effects include ear irritation, physiological effects, loss of hearing, loss of focus, resulting in decreased production, ringing in the ears, fatigue, altering the functioning of the human system, and sleeplessness. As a result, it was proposed that, while the danger limit for the occurrence of hearing impairment and deafness in unprotected ears for an eight-hour exposure is 90 dB, a warning limit of 85 dB should be established in most industrial environments as a noise level to which workers should never be exposed without appropriate ear protection because exposures at and above this level may be hazardous (Berkhout, et al., 2023). Assessing quarry noise levels and dust emissions is critical to protecting the environment as well as public health (Pham et al., 2024). Senzaki et al. (2024) explained that excessive noise can cause hearing damage and disrupt nearby communities. Dust emissions provide a respiratory risk and contribute to respiratory illnesses. Furthermore, environmental factors influence air and soil quality. Understanding and controlling these issues is critical for regulatory compliance, worker safety, and environmental sustainability. Comprehensive assessments lead the implementation of effective control measures, promoting sustainable quarrying practices that balance economic, environmental, and public health concerns. Regular monitoring, as described in this paper, aids in early detection, allowing for timely actions to correct issues and improve the overall safety and sustainability of environmentally friendly quarrying activities.

2. Materials and Methods

2.1 The Location of Kristal Vountein Granite Quarry

The study area, Kristal Vountein Granite Quarry is located at Salata, Village, Ipetu Jesa, Osun State, Nigeria. It was formally established in August 2016. The company is a small-scale industry comprising 30 members of staff (5 non-professionals, and 25 professionals including semi-skilled and unskilled workers. It has a production department (drilling, blasting, haulage and crushing sections), an administrative department (administrative and sales sections), a Mechanical department (maintenance of equipment) and a Security department (for safeguarding the quarry). Figure 1 presents the geology of the case study area including the quarry.

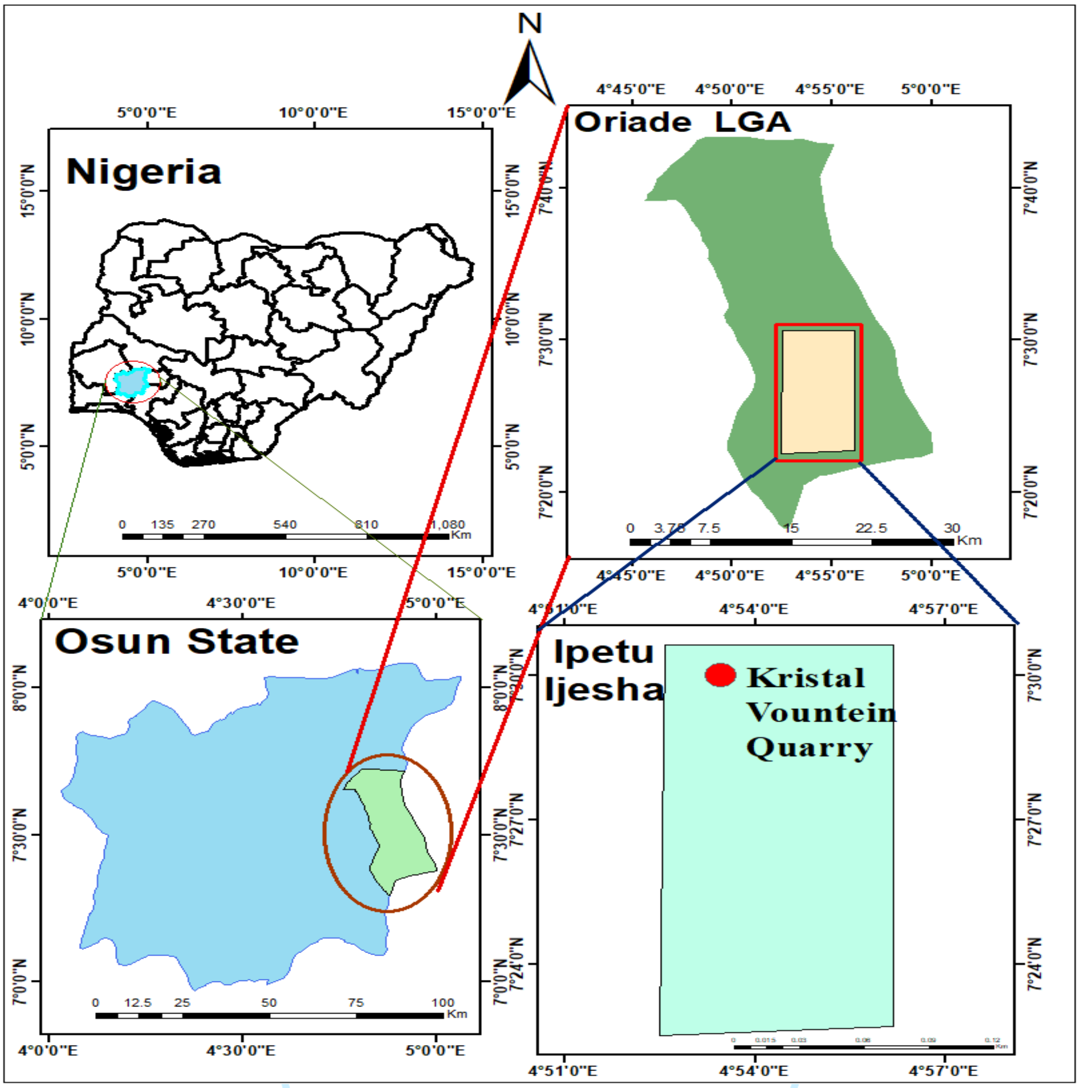

Fig. 1 The Location of Kristal Vountein Granite Quarry

2.2 Determination of the Concentrations of PM10 and PM2.5

Concentrations of PM10 and PM2.5 were determined using the Teflon filter Particulate counter. It was carried out at different places within the Quarry like the crushing point, 50m away from the crushing point, 100m, 150m, 200m and 250m away from the crushing point. The sampling points were denoted L1, L2, L3, L4, L5 and L6. Gravimetric method was used to determine the concentrations of PM10 in the sampled air. Air sample was drawn through a sampling inlet at a constant volumetric flow rate of 18.9 l/min. The sample air stream passes downward through a filter tape collection substrate where the particles are deposited. The filter tape was then shifted to the beta source/detector to measure the attenuated count rate due to the presence of collected particles. The ambient mass concentration of the PM10 in the collected air samples was determined with a resolution of approximately 3 μg m^{-3} of collected particles for a 1-h sampling period. A microcomputer-based data acquisition system controls the filter tape drive, monitors temperature and pressure, calculates flow rate and mass concentration values, and provides the necessary analog outputs for a telemetry system. The average PM10 concentrations in each location was determined by dividing the net weight gain of the filter by the total volume of air sampled. The concentration of PM10 was calculated using Equation 1. The test was repeated three times at each location and the average recorded.

$$PM10 = (Wf - Wi)X\ 10^{6}/vol \qquad (1)$$

where:

PM10 means particles with a diameter of 10μm or less,

Wf and Wi are final and initial weights of filter collecting PM1O particles and 10^6 is the conversion factor of g to μg.

PM2.5 were later estimated from the PM10. The test was repeated three times at each location and the average recorded.

2.3 Estimation of Air Quality Index

Air Quality Index (AQI), a health risk assessment was evaluated for PM10 and PM2.5 using Equation 2 as provided in the guidelines for reporting air quality index (AQI) (Rim-Rukeh, 2015) and compared with the descriptor of AQI otherwise called EPA table of breakpoints (USEPA, 2013) presented in Table 1.

$$I = \frac{(I_{high} - I_{low})(C - C_{low})}{C_{high} - C_{low}} + I_{low} \qquad (2)$$

where:

I is the AQI for pollutant; C is the concentration of pollutants, C_{high} is the concentration of breakpoint that is greater than or equal to C, C_{low} is the concentration of breakpoint that is less than or equal to C, $I_{low}$is the AQI value corresponding to C_{low} and I_{high} is the AQI value corresponding to C_{high}.

Table 1 EPA’s Table of Breakpoints

PM_{10} (μg/m^3)	$PM_{2.5}$ (μg/m^3)	AQI	Category
0–54	0.0–12.0	0–50	Good
55–154	12.1-35.4	51–100	Moderate
155–254	35.5–55.4	101–150	Unhealthy for Sensitive Groups
255-354	55.5-150.4	151-200	Unhealthy
355–424	150.5–250.4	201–300	Very Unhealthy
425–604	250.5–500.4	301–500	Hazardous

2.4 Determination of Noise level

The noise level in the study area was determined using an LT Lutron SL – 4012 sound level meter which measures the level of sound ranging from 30 to 130 dB. The sound levels were taken at different distances (every 50m) from the crusher which was identified as the most prominent source of steady noise pollution. It was carried out at different places within the Quarry like the crushing point, 50m away from the crushing point, 100m, 150m, 200m and 250m away from the crushing point. The sampling points were denoted L1, L2, L3, L4, L5 and L6. The readings of different areas at different distances were taken directly from the interface of the instrument and recorded. The readings were taken three times at each location and the average recorded.

2.5 Statistical Analysis

All parameters were analysed using MS – Excel, IBM SPSS Statistics 21 and MINITAB 19 software to evaluate statistical parameters (frequency, standard deviation, mean and coefficient of variation) utilised for this study.

3. Results and Discussion

The results of the noise and dust analysis in the study area are presented in Table 2. The monitoring was done at 6 points at 50-meter differences. The result as shown in Table 2 revealed that the measuring distance had an impact on the dust and noise level. According to the assessment report and World Health Organization standards, the safe distance for the case study mine ranges from 100 meters away. The dust level including PM10 and PM2.5 were monitored at 50, 100, 150, 200, and 250 m, respectively.

Table 2 Noise Levels and Dust Concentration

Sampling points	L1	L2	L3	L4	L5	L6
Distance from the crusher (m)	**0**	**50**	**100**	**150**	**200**	**250**
Latitude (N)	07°29’28.2”	07°29’27.8”	07°29’27.9”	07°29’27.4”	07°29’27.4”	07°29’26.9”
Longitude (E)	004°53’51.4”	004°53’51.6”	004°53’51.7”	004°53’51.9”	004°53’52.1”	004°53’52.3”
Noise (dB)	85.8±2.6	80.4±2.4	73.1±1.9	67.8±2.1	63.3±1.7	58.5±1.7
PM10 (μg m^{-3})	364.2±19.7	347.1±18.5	281.2±16.2	182.7±17.1	98.3±15.6	84.1±12.3
PM2.5 (μg m^{-3})	169.8±9.7	165.4±8.6	133.7±9.1	86.5±7.6	56.5±6.9	50.7±8.1
AQI (PM10)	211.8±13.1	197.4±11.3	164.4±10.1	114.1±10.9	71.9±9.7	65.1±9.1
AQI (PM2.5)	219.9±11.9	215.1±11.3	189.3±9.5	167.2±8.3	151.0±7.6	137.2±6.9

3.1 PM10 and PM2.5 Concentrations

The results of the dust survey of the Kristal Vountein Quarry are given in Figure 2. PM10 at the crusher at 50, 100, 150, 200 and 250 m from the crusher were 364.2±19.7, 347.1±18.5, 281.2±16.2, 182.7±17.1, 98.3±15.6 and 84.1±12.3 μg m^{-3}, respectively. PM2.5 at the crusher; 50, 100, 150, 200 and 250 m from the crusher were 169.8±9.7, 165.4±8.6, 133.7±9.1, 86.5±7.6, 56.5±6.9 and 50.7±8.1 μg m^{-3}, respectively. PM10 as well as PM2.5 concentrations were highest at the crusher and the decreases as distance from the crusher which is the source of pollution increases. These decreases as distances increase from the source of pollution align with the WHO (2016). The concentration of PM10 at all sampled points was more than the maximum daily exposure limit of 45 μg/m^3 set by WHO (2016). Similarly, concentrations of PM2.5 at all sampled points were more than the maximum daily exposure limit of 15 μg/m^3 set by WHO (2016). The workers and those in the vicinity of the quarry are therefore prone to increased occurrence of respiratory and cardiovascular diseases which can lead to subsequent reduction in life expectancy. Most vulnerable are persons with pre-existing diseases.

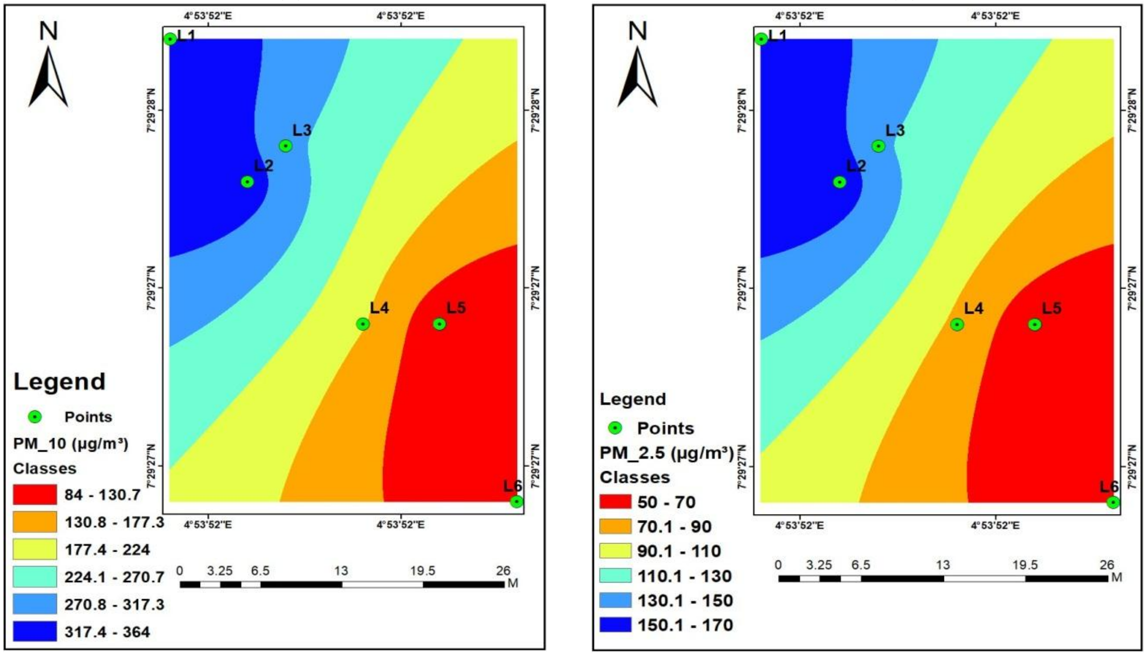
(a) (b)

Fig. 2 Spatial Plot of the concentration of (a) PM10 and (b) PM2.5 at Krista Vountein Quarry

3.2 Environmental Health Risk Assessment

Air Quality Index (AQI) for PM10 and PM2.5 was evaluated to estimate the environmental health risk due to dust generation as a result of quarrying at the crusher at distances of 50 m apart beginning from 0 to 250 m. AQI of 212 and 220 for PM10 and PM2.5 were obtained at the crusher, respectively (Figure 3). These values indicated that workers' exposure to both PM10 and PM2.5 is very unhealthy. The particulate matter contained in polluted ambient air due to mining such as this, could result in human health problems and contribute to the low life expectancy of around 58.4 and 55.75 years in Osun State and Nigeria, respectively.

AQI of 197.4±11.3 and 215.1±11.3 for PM10 and PM2.5 were equally obtained at a distance of 50 m from the crusher, respectively. These values showed that human exposure to PM10 was unhealthy while PM2.5 was very unhealthy. AQI of 164.4±10.1 and 189.3±9.5 were obtained for PM10 and PM2.5 at a distance of 100 m from the crusher. These values showed that human exposure to PM10 and PM2.5 were both unhealthy. AQI of 114.1±10.9 and 167.2±8.3 for PM10 and PM2.5 respectively were obtained at a distance of 150 m from the crusher. These values showed that human exposure to PM10 was unhealthy for sensitive groups while PM2.5 was unhealthy. AQI of 71.9±9.7 and 151.0±7.6 were obtained for PM10 and PM2.5 at a distance of 200 m from the crusher. These values showed that the level of health concern of human exposure to PM10 was moderate while that of PM2.5 was unhealthy. AQI of 65.1±9.1 and 137.2±6.9 for PM10 and PM2.5 respectively were obtained at a distance of 250 m from the crusher. These values showed that the level of health concern of human exposure to PM10 at a distance was moderate while PM2.5 was unhealthy for sensitive groups.

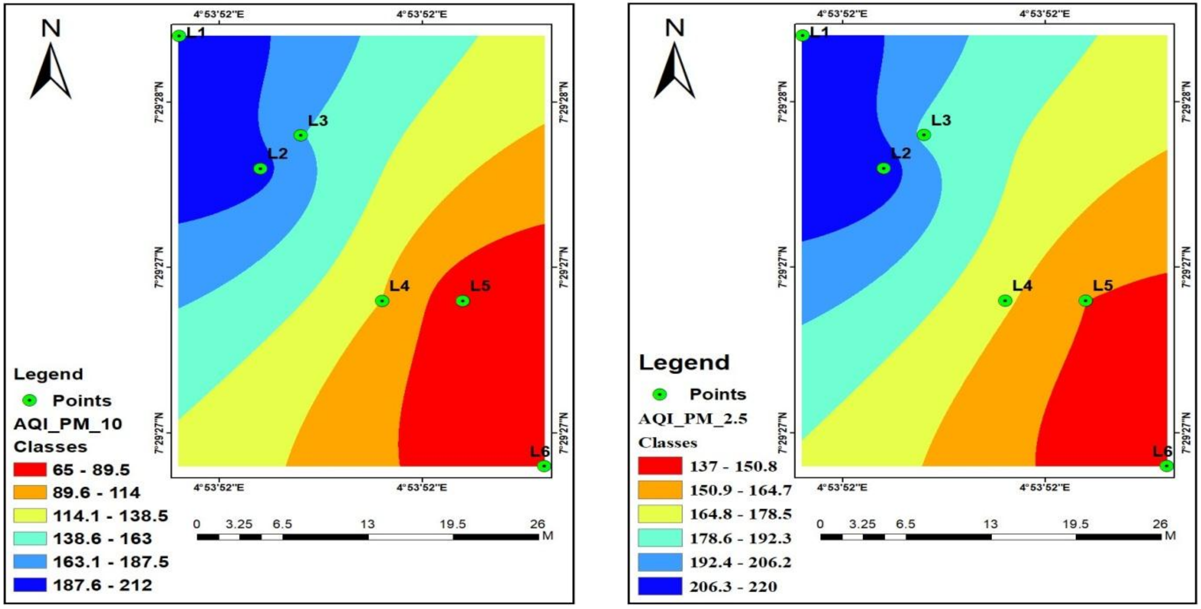
(a) (b)

Fig. 3 Spatial Plot of the Air Quality Index due to (a) PM10 and (b) PM2.5 at Krista Vountein Quarry

3.3 Noise Level

Noise is a form of environmental pollution which affects human health and the health of other organisms in the ecosystem. WHO (2022) stipulates a maximum sound level of 70 dB (A). The noise level at the crushing point was found to be 85.8 dB. While 80.4 dB, 73.1 dB, 67.8dB, 63.3 dB and 58.8 dB were obtained at 50, 100, 150, 200 and 250 m from the crusher, respectively (Figure 4). The highest measured noise level obtained was from the crushing point 85.8 dB. Whereas the minimum noise level was found at 250 m away from the crushing point at 58.5 dB. This noise level at the crusher and 50 m and 100 m from the crusher are above the permissible limit of 70 dB while those obtained at 150 m, 200 m and 250 m complied. Exposure to noise frequency exceeding 85 dB has been demonstrated to cause hearing loss, which may be temporary or permanent (Deiters, 2024). The workers of Krista Vountein Quarry especially those at the crusher are working at a level which is not dangerous to their health they should therefore be provided with appropriate ear protection.

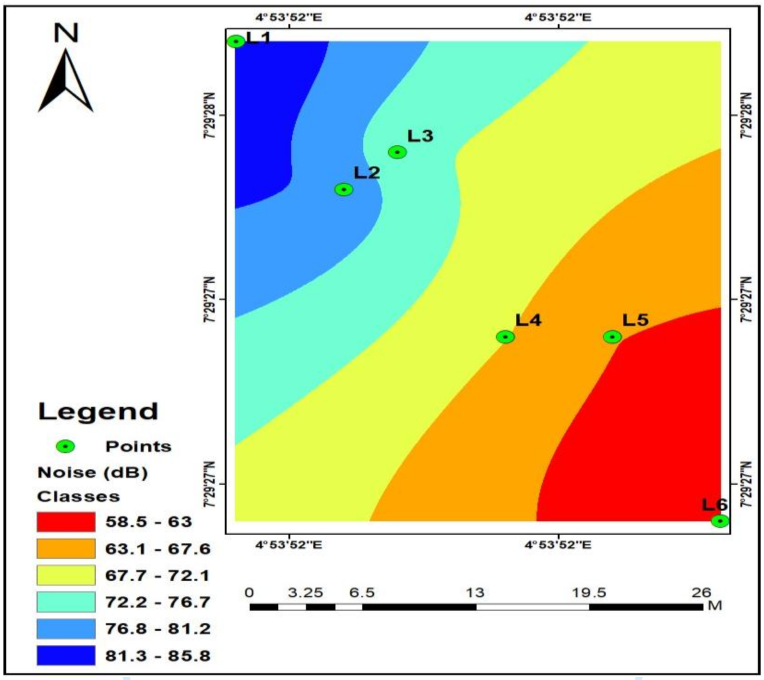

Fig. 4 Spatial Plot of Noise at Krista Vountein Quarry

4. Suggestions for Dust and Noise Control

Based on the assessment result presented in Table 2, it was noted that there was no particular measure being observed at Kristal Vountein Quarry to control the noise in the quarry since the maximum noise level produced is below the acceptable limit of 90 dB for workers within 8 hours, dust control measures include Wet Dust Suppression System and Dry Dust Extraction System. However, the following measures are suggested for improved dust control:

1. Purchase of new machines and maintenance of old ones;
2. Personal Protective Equipment (PPEs) should be provided and the use enforced;
3. The reduction of exposure period is necessary to avoid the injurious impact of dust;
4. Wet blasting - Spraying could be done before blasting; and
5. Dust extraction equipment, such as filters, should always be attached to the exhaust on drill rigs (Finn, 2023).

Dust exposure control as well as environmental protection and health safety procedures, should be prioritized by mining companies' top-level management. It is important to organize continuous training for mine workers to awaken their awareness and emphasise its priority. Management should encourage staff by introducing reward systems to promote safe procedures and not just focus on increasing productivity. Integration of comprehensive prevention and control procedures into well-managed and sustainable production processes at the workplace and the involvement of management and workers as collaborators will improve occupational safety and environmental protection. Furthermore, the promotion of dust and noise reduction or their elimination at the source is also needed to protect the environment and mine workers. An environmentally friendly production design, which will reduce dust generation should be used. Training of workers on practices that will reduce dust and how they perform their tasks, that is, exposure to noise and dust while performing their duties, is essential for promoting environmental and health protection practices. Essential tools for the training of workers may include footage of responsibilities with real-time measurement of dust concentrations and various noise levels. Dust lamp is another cost-effective tool, which makes the dust visible and may be used together with the tasks' video for staff training.

It is essential to prioritise activities that will bring about the reduction and avoidance of dust before considering personal protective equipment (PPE), especially those for respiration. A mask respirator is not an easy equipment that can be worn for a long period because it often makes people uncomfortable, especially when the weather is hot or cramped.

This condition tempts workers to remove their masks even when they are aware of the consequences. Furthermore, uncontrolled dust can be transported through the air to areas far from the source of generation to impair people's health. Therefore, the best approach is to minimise dust production in the work area, especially when it is difficult to eradicate. Another issue is that the infallibility of PPE in all conditions cannot be guaranteed as they may not be able to provide maximum protection at all times. More so, they can only protect human beings and not the environment. Finally, respiratory protection equipment can be cost-effective as their careful cleaning at all times improves their effectiveness.

Therefore, management of mining organisations should work on the development of comprehensive noise and dust prevention and control systems to enhance the safety of workers and protect the environment. This is necessary to avert the possible damage that can result from fine particles such as reduction of atmospheric visibility, damage to vegetation and impairment of animal and human health.

5. Conclusion

The study revealed that the concentrations of the quarry dust were higher than the prescribed limits. The dust concentration at the crusher and all distances from the crusher were higher than the prescribed limits. The study found that dust concentration in the air reduces at increasing distance from the crusher. Also, the health risk awareness levels of the workers at the quarry were high but their level of compliance with the usage of PPE was very low. Workers were exposed to high concentrations of dust and their inadequate adherence to the use of protective clothing and gear exposed them to a high risk of respiratory concern such as lung, skin and eye diseases. The study also revealed that the noise level in the study area was slightly below the danger limit of exposure within 8 hours but above the recommended exposure limit of 70 dB. The implication is that the workers are running at little risk of having hearing problems or deafness. The noise level should be further reduced.

5.1 Recommendations

1. A comprehensive environmental management system should be deployed to manage noise and dust production.
2. Adherence to approved dust limit standards should be enforced through periodic environmental audits.
3. A sensitisation campaign programme should be organised for quarry workers to emphasise the adverse health effects of exposure to quarry dust and the penalty for non-compliance with the effective usage of personal protective equipment.
4. Noise level should be properly monitored to ensure compliance with safety guidelines and areas with increasing decibels should be identified for appropriate interventions.

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Statements and Declarations

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Declaration of Conflicts:

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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