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Regional Case Study

Mining Noise Pollution: A Case Study of a Crushing Plant in Sintang

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Abstract
The crushing plant in the mining industry produces noise levels above the allowable noise level, potentially causing hearing damage to mining workers. One way to early control this is by mapping the noise distribution in the area. The noise distribution mapping was based on noise intensity. The noise intensity measurement was done using a sound level meter according to Indonesian national standards 7231:2009. The noise exposure analysis was based on the NIOSH formula and Indonesia's national standard 7570:2023. The study's results revealed that noise levels at the source exhibited an intensity of approximately 95-103 dB. The noise propagation pattern extended from the southwest to the northeast, with an intensity of approximately 68-93 dB. The highest noise intensity was observed in the vicinity of the first jaw crusher, exceeding 100 dB, with a daily exposure time in this area of 6-12 minutes. Prolonged exposure to high noise levels can potentially lead to auditory damage. Therefore, the implementation of noise control measures, including using personal protective equipment and the installation of appropriate safety signage, is imperative.

Keywords: Andesite mining; crushing plant; noise

1. Introduction

The andesite processing in the mining industry in Sintang Regency, Kalimantan Barat, uses a crushing plant system. The processing purpose is to reduce the size of the stone to a suitable size for the market, as well as to increase its quality and purity (Anggraini and Octova, 2020; Sugianto et al., 2020; Utami et al., 2020; Putri et al., 2019; Rahmi and Murad, 2018; Nobyl et al., 2016). The equipment used in the crushing plant includes a belt conveyor, a vibrating screen, and a jaw plate on the jaw crusher. The processing of the mineral resource is divided into four stages: comminution (size reduction), sizing (size separation), concentration (purity increase), and dewatering (reduction of water content) (Asri et al., 2019; Muhammad et al., 2016). The large-scale processing of rocks has the potential to produce noise levels exceeding the allowable noise level (ANL) (Ningrum et al., 2023; Utami et al., 2020).

Millions of European employees are exposed to industrial noise (Mocek, 2020). Noise is a sound that exceeds the ANL under specific time and environmental conditions(Nasution, 2019; Gani et al., 2018; Prihastuti, 2018; Lestary and Harmon, 2017; Praditami, 2016). The ANL for industrial zones is 70 dB (Menteri Negara Lingkungan Hidup, 1996). If noise levels continuously exceed the ANL, it can cause temporary and permanent hearing damage to mining workers (Olusanya et al., 2019). Based on data from the World Health Organization (WHO), in 2000, there were 250 million people worldwide suffering from hearing loss, and 30-56% were in Southeast Asia and 4.6% in Indonesia (Waskito, 2008). Other effects experienced by workers exposed to continuous noise include stress, reduced concentration, decreased productivity, and discomfort (Zwagery and Dewi, 2019; Handayani et al., 2020; Susanto et al., 2021). Based on Ningrum et al. (2023) research, the impact of noise felt by workers in the andesite mining was hearing, communication, and psychological disorders. Therefore, it is necessary to map noise distribution in the area.

Previous research on the mapping of noise caused by crushing plant activities has been conducted by Putri et al. (2020), Utami et al. (2020), and Nata et al. (2022). Previous studies showed that noise levels exceeded the ANL (Putri et al., 2020; Utami et al., 2020; Nata et al., 2022). However, Putri et al. (2020) and Nata et al. (2022) only mapped noise around the crushing plant without considering the wind direction. Utami et al. (2020) addressed this by mapping noise based on wind direction. However, the study did not measure noise levels near the noise sources, such as jaw and cone crushers.

This research aims to address the gaps in previous research by examining the distribution of noise from noise sources and the area around the crushing plant, both in the direction of the wind and around the plant. The study's results will visually represent the noise distribution, intensity, and exposure levels. This research is relevant because it focuses on the mining industry, which involves crushing rocks using crushers. Furthermore, the findings can be used to inform noise control policies.

2. Methods

The research method used in this study was quantitative. Quantitative research emphasizes testing theories by measuring research variables with numbers and performing data analysis. The research data consisted of both primary and secondary data. Primary data was direct measurements of noise levels taken in the field. Secondary data included the work hours of mine workers around the crushing plant area and the Mining License.

2.1 Noise Measurement Location

Noise measurements were conducted at one of the andesite mining industries in Sintang Regency, West Kalimantan. The noise measurements were carried out at noise sources and around the crushing plant area (Figure 1). The noise source measurements were taken at 1st jaw crusher, 2nd jaw crusher, and cone crusher. The distance in each noise source measurement area was 2 meters. The area surrounding the crushing plant was divided into four noise zones: A, B, C, and D. Zone A was a location for collecting noise data with the wind. Zone B, C, and D were locations for collecting noise data against the wind direction. The starting and ending points of measurement were at a distance of 5 and 35 meters, with an interval of 10 meters. Zone A closed to the jaw crusher 2. Zone B was near the conveyor belt, which carries 2×3 cm rocks, and the cone crusher. Zone C was near the conveyor belt, which carried stone products measuring 2×1 cm and 1×1 cm. Zone D closed jaw crusher one and the conveyor belt, which carries rocks that have been reduced to sizes of 1×1 cm and 0.5 cm. The calculation of noise levels was based on the prediction equation of Sasongko and Hardiyanto (2000) in Equation (1).

$$L_2 = L_1 - 20 \log \left(\frac{r_2}{r_1}\right) \text{ dB(A)} \quad (1)$$

Information:
L_1 = Noise level at a distance r_1 from the source (dBA)
L_2 = Noise level at a distance r_2 from the source (dBA)

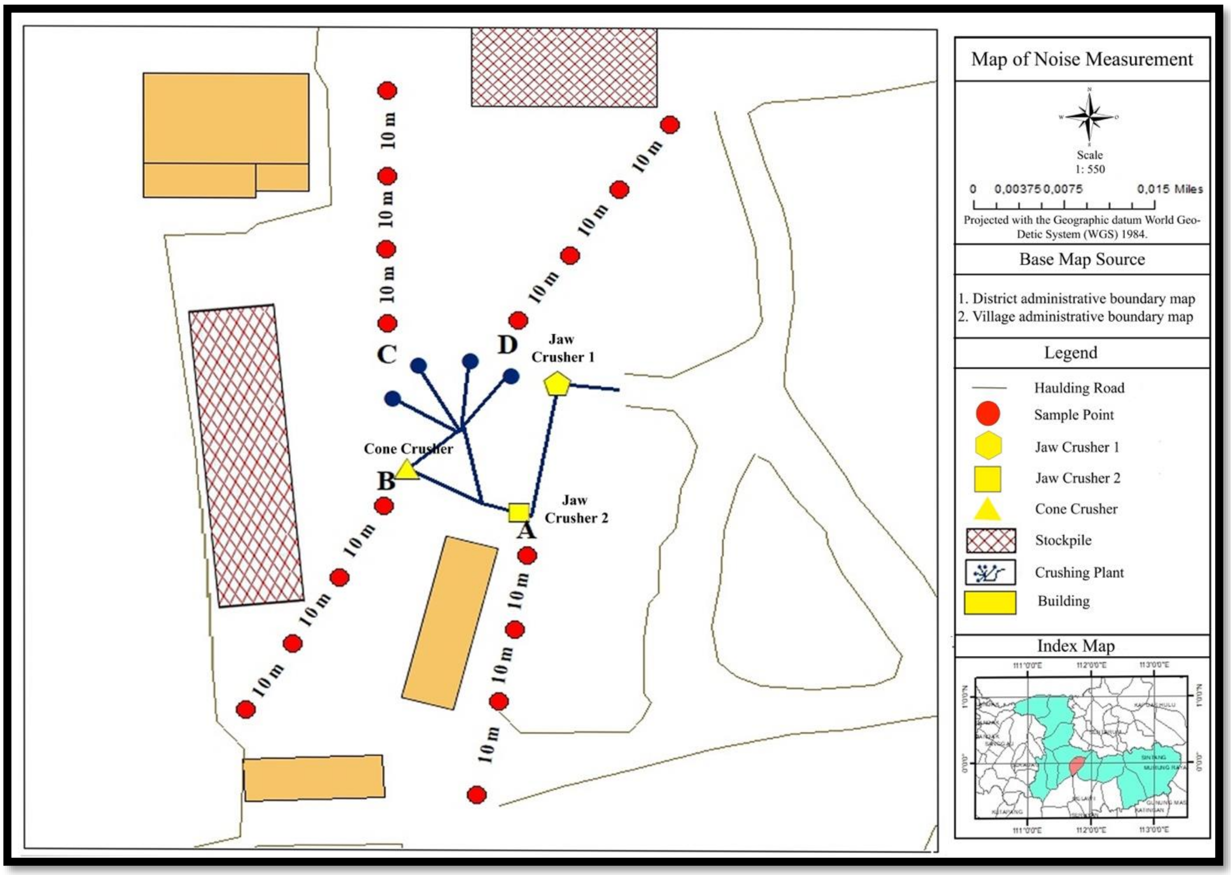

Figure 1. Noise measurement points

2.2 Noise Measurement

Noise measurement was carried out in the morning (08:00), afternoon (13:00), and evening (16:00) with wind and against wind conditions. Noise intensity measurements were taken using a sound level meter, and the measurement points were determined using a Global Positioning System. Noise level measurements were taken for 10 minutes, with readings every 5 seconds (Badan Standarisasi Nasional, 2009).

2.3 Data Processing and Analysis

The noise level values obtained from the sound level meter were calculated based on the Indonesian National Standard 7231:2009 (Badan Standarisasi Nasional, 2009). The formula for calculating equivalent continuous noise intensity (LAeq) can be seen in Equation (2). The results of the LAeq calculations were processed in a mapping application to visualize the noise distribution pattern.

$$L_{Aeq} = 10 \log \frac{1}{T} \sum_{Ti}^{T} Li\,Ti.\,10^{0,1Li} \text{ dB(A)} \quad (2)$$

Information:

L_{Aeq}: Equivalent continuous noise level

L_i : Average noise level at a specific time interval

T : Measurement interval

T_i : Measurement time interval (Badan Standarisasi Nasional, 2009)

The equivalent sound level intensity (LAeq) calculation results were analyzed using the threshold values specified in Indonesia's national standard 7570:2023 (Badan Standardisasi Nasional, 2023). The intensity values were also processed into a mapping application to visualize the distribution of noise pollution. According to the Indonesian Ministry of Health Regulation No. 70 of 2016, the recommended exposure time is 85 dBA for 8 hours/day (Kementerian Kesehatan, 2016). However, according to Indonesia's national standard 7570:2023, the intensity noise level of 100 dB(A) for 15 minutes daily (Badan Standardisasi Nasional, 2023) was acceptable maximum noise exposure. The formula used to calculate the duration of noise exposure was Equation (3) by the National Institute of Occupational Safety and Health (NIOSH) (NIOSH, 1998). The noise exposure calculation result has been compared with the average working hours of mining workers, which is 10 hours per day.

$$T = \frac{480}{2^{(l-85)/3}} \quad (3)$$

Information:
T : Exposure time
L : Noise level (dBA)
480: 8 hours of work/day, 1 hour = 60 minutes
85 : Exchange rate (dBA)
3 : The relationship between noise intensity and noise level

3. Result and Discussion

3.1 Noise Intensity Level Analysis

The primary noise source in the study area originated from the crushing machine operations, which generated vibrations and noise through collisions and friction between the machine and the stone (Roberts et al., 2017; Mocek, 2020; Naeini and Badri, 2024). Based on the measurements and analyses conducted, it has been determined that noise intensity levels revealed significant variations across different operational areas of the crushing plant. The first jaw crusher produced the highest noise levels, followed by the cone crusher, and the second jaw crusher (Table 1). These variations correlate with machine capacities. This finding corroborates the study by (Sihombing et al., 2024), which established a positive correlation between machine capacity and generated noise levels. The noise intensity produced by these machines depended on the number of cylinders and engine speed (Sudrajad and Gurning, 2016).

Table 1. Equipment performance and noise output comparison

Noise sources	Noise intensities (dB)	Machine capacities
The first Jaw crusher	99-103	20 m^3/hour, input 10-15 cm
Cone crusher	97-98	15 m^3/hour, input 4 cm
The second Jaw crusher	95-96	10 m^3/ hour, input 6-7 cm

Spatial analysis demonstrated a clear inverse relationship between noise intensity and distance from the source (Figure 2). Points A0, B0, C0, and D0, proximal to the crushing plant, recorded significantly higher noise levels (M = 91.31 dB) compared to the more distal points A3, B3, C3, and D3 (M = 72.70 dB). This spatial distribution pattern aligns with the Doppler effect theory (Landau and Lifshitz, 1975).

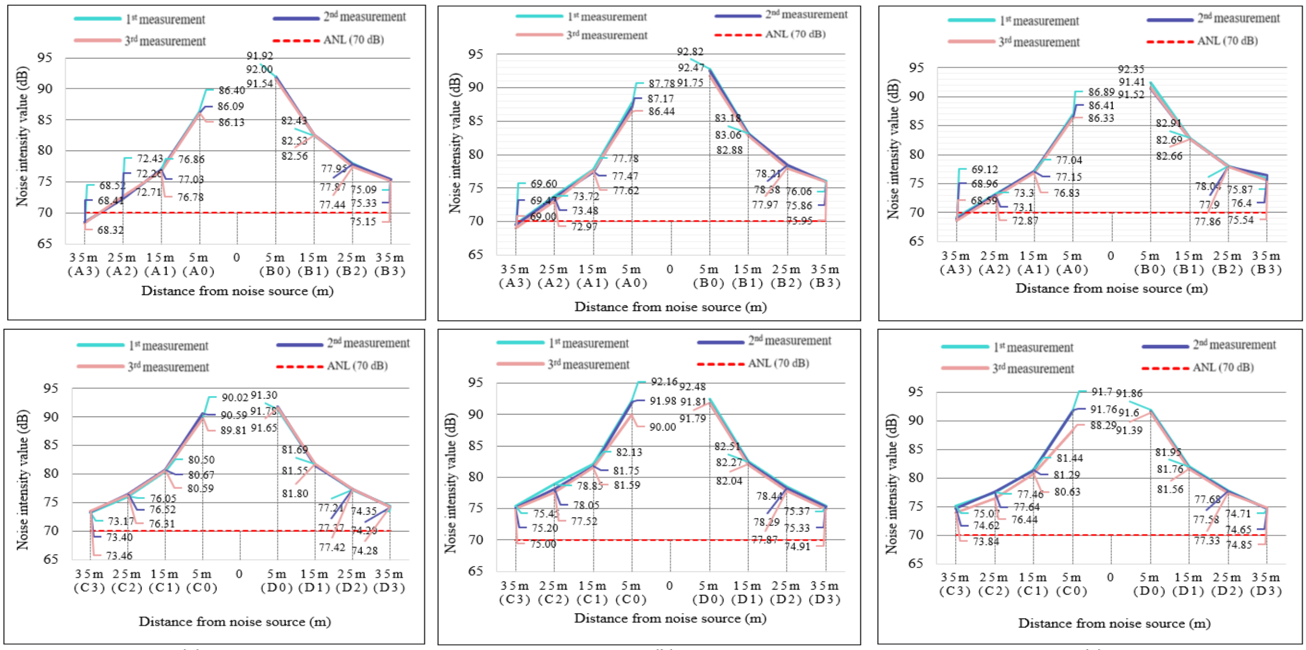

Figure 2. Noise intensity values in zones A, B, C, and D at measurement time (a) morning (08:00); (b) noon (13:00); and (c) afternoon (16:00)

The highest noise intensity levels were recorded during the first day of measurement, coinciding with increased transportation activities due to the high demand for split stones. Peak noise levels were observed during daylight hours, corresponding to the most intense mining operations.

3.2 Noise Distribution Pattern Analysis

The noise distribution was mapped based on intensity values and classified by color, with red indicating values above the threshold limit and orange to purple representing values below the standard limit (Figure 3). Noise distribution mapping revealed that intensity values exceeded the Indonesian National Standard 7570:2023 limit of 100 dB(A) at the first jaw crusher (Badan Standardisasi Nasional, 2023). The distribution pattern against the wind direction spread from Southwest to Northeast in areas B, C, and D, while the windward distribution in area A extended from Southwest to Northwest. Wind direction significantly influenced the noise distribution pattern, with higher intensity values observed against the wind direction. This phenomenon, likely due to sound wave interactions with air currents, is consistent with acoustic propagation models in open environments (Sasmita et al., 2018).

Environmental factors, including air temperature, influence noise intensity (Khasanah, 2017; Sánchez-Fernández et al., 2021). Higher air temperatures corresponded to increased noise intensity, while higher humidity led to decreased air density and, consequently, lower noise levels (Sasmita et al., 2018). The absence of buffer zones and vegetation in the study area, primarily open land used as mining roads, contributed to the generally high noise levels. Our findings support previous research indicating that vegetation can significantly reduce noise levels by up to 11 dB (Ow and Ghosh, 2017), suggesting potential for noise mitigation strategies.

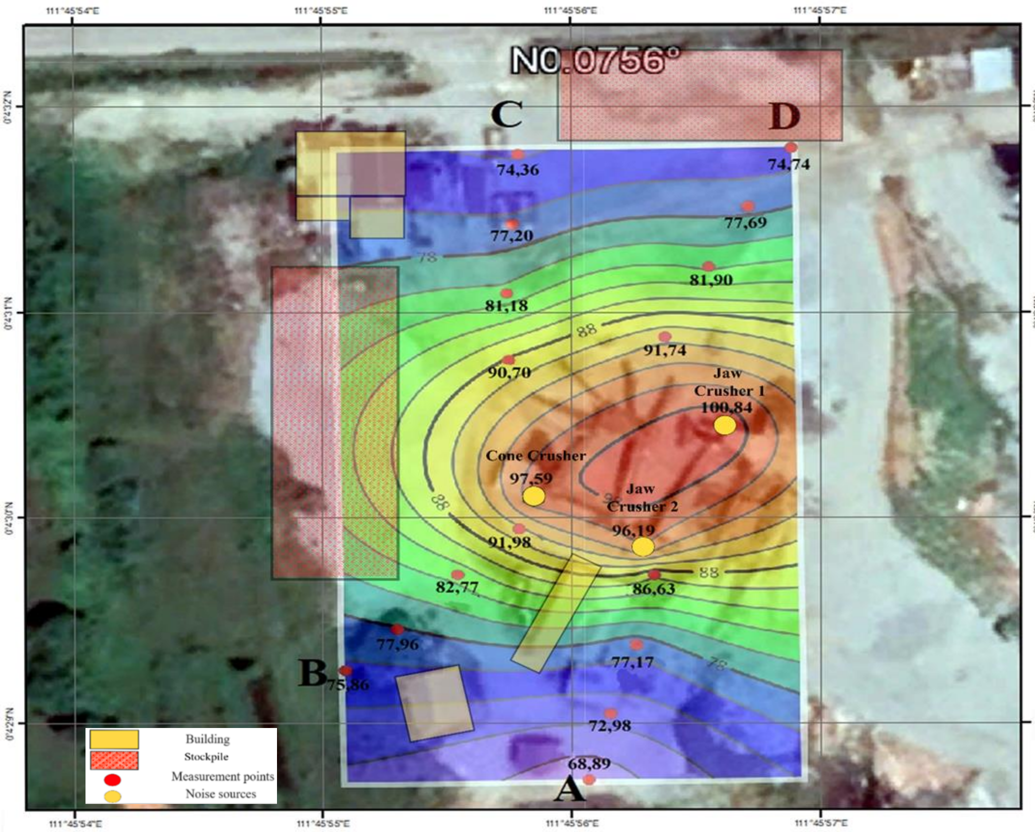

Figure 3. Noise distribution mapping

The noise distribution map indicated that most areas within a 5-25 m radius of the crushing plant experienced noise intensities exceeding 70 dB. Notably, the noise intensity value at the first jaw crusher surpassed the allowed standard, which is a potential hearing impairment risk for workers in the mining area (Gyamfi et al., 2016). Therefore implementation of noise control measures, such as the use of ear protection equipment (Tekin, 2020; Fu et al., 2022) and safety signs (Azman et al., 2022), was deemed necessary.

3.3 Noise Exposure Analysis

Noise exposure, the maximum time interval for workers to be present in a location with a specified noise level, was measured in hours or minutes per day (Kementerian Kesehatan, 2016). According to Indonesia's national standard 7570:2023, the maximum allowable exposure time in areas with a noise intensity of 100 dB(A) is 15 minutes daily (Badan Standardisasi Nasional, 2023).

Noise exposure durations varied across different areas of the crushing plant (Figure 4). The first jaw crusher area, with the highest noise intensity, permitted the shortest exposure time (6-12 minutes), below the threshold set by Indonesian National Standard 7570:2023. The second jaw crusher area allowed for 32-39 minutes of exposure, while the cone crusher area permitted 24-30 minutes.

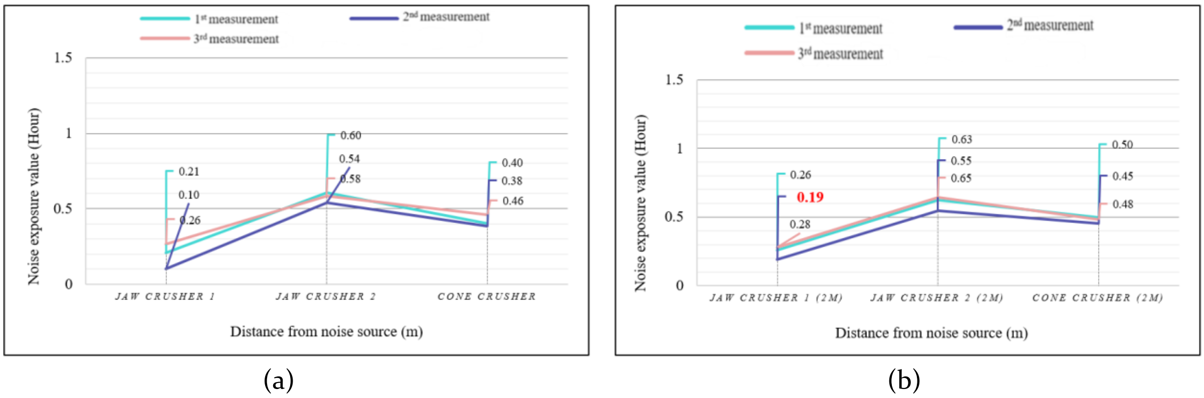

Figure 4. Noise exposure value in the source area measured in (a) morning (08:00) and (b) noon (13:00)

The inverse relationship between noise intensity and exposure duration demonstrates that an increase in noise intensity is inversely proportional to the duration of noise exposure. The first jaw crusher exhibits significantly higher noise intensity (>100 dB) compared to other noise sources in the vicinity. This heightened acoustic output is attributed to the machine's superior capacity (20 m^3/h), which exceeds that of other equipment in the area. The substantial power requirements for crushing large-scale rock formations result in markedly elevated noise levels. Consequently, the exposure duration to extreme noise in this zone is notably brief relative to other noise-generating locations within the facility.

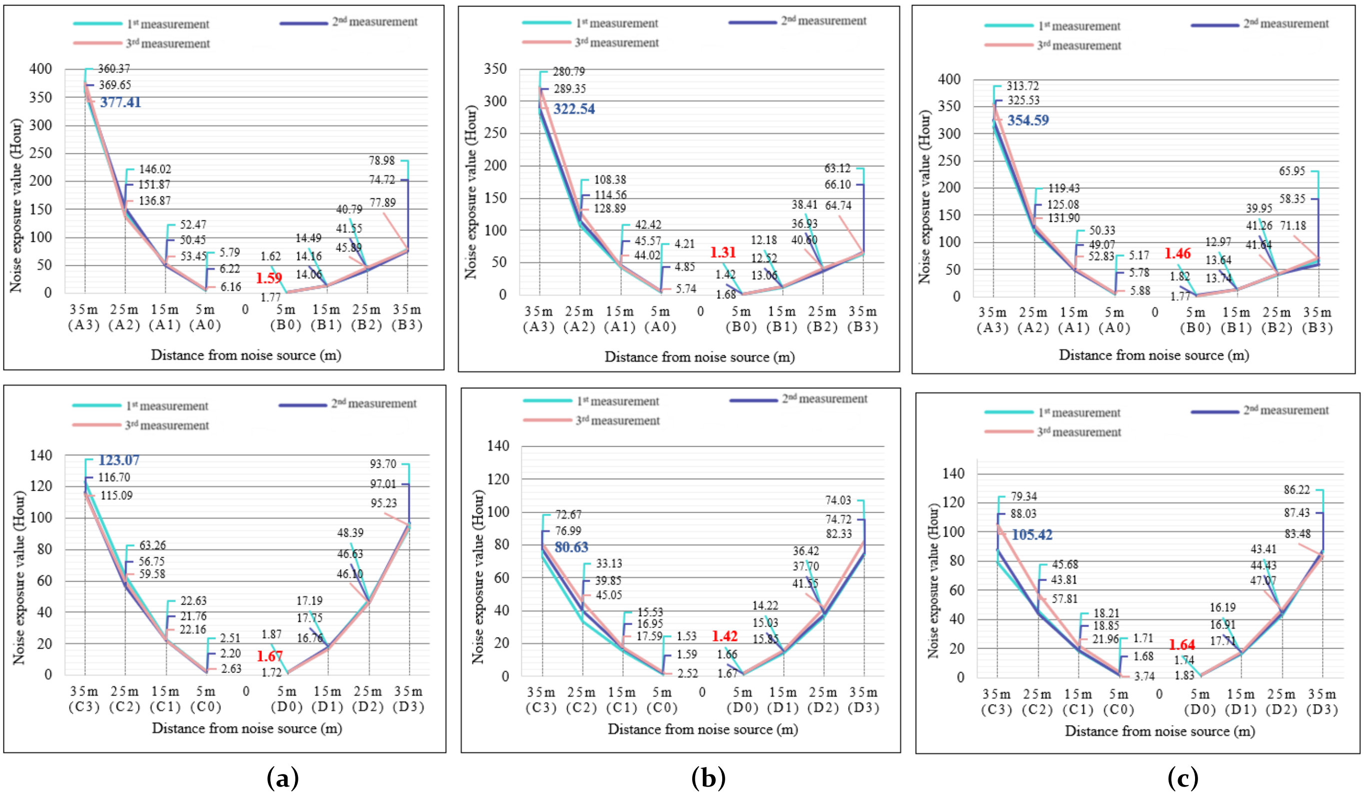

Figure 5. Noise exposure value in crushing plant area in (a) morning (08:00); (b) noon (13:00); and (c) afternoon (16:00)

Spatial analysis of noise exposure durations revealed that the shortest (78 minutes) occurred at point B0, located 5 m from the noise source. Conversely, the longest duration (377 hours) was observed at point A3, situated 35 m from the noise source (Figure 5). These variations were attributed to the proximity to noise sources and the distribution of heavy equipment activities across the study area.

The spatial distribution of heavy equipment activity revealed variations in noise intensity across different zones. Zone B was characterized by wheel loader operations for rock transportation, while Zone A remained relatively inactive. The highest concentration of heavy equipment activity was observed in C3, adjacent to the mining site's entry point. Temporal variations in wheel loader operational patterns were observed between the first and second measurements. The initial measurement indicated rock transfer to the stockpile in Area D (rock sizes of 0.5 cm and 1 x 1 cm), whereas the subsequent measurement showed relocation to Area C (rock sizes of 2 x 1 cm and 2 x 3 cm).

Prolonged exposure to high noise levels poses significant health risks for workers (Lai and Huang, 2019), including hearing disorders (Amar et al., 2019; Tekin, 2020), work fatigue (Li et al., 2022), and psychological disturbances such as increased emotional stress, discomfort, lack of concentration, and insomnia (Hahad et al., 2019; Indrayani et al., 2020; Esmaielpour et al., 2022). The severity of these impacts is influenced by both the intensity and duration of exposure (Gunawan and Marsum, 2015; Gong et al., 2022), underscoring the importance of implementing appropriate noise control measures and adhering to exposure guidelines in mining operations.

Implementation of noise control measures, such as advanced ear protection equipment (Fu et al., 2022) and enhanced safety protocols and safety signs (Azman et al., 2022), is strongly recommended. These findings contribute to the broader understanding of occupational noise exposure in mining operations and emphasize the need for industry-wide adoption of more stringent noise management practices.

4. Conclusions

The highest noise intensity observed in the source area (jaw and cone crusher) ranged from 95-103 dB. This elevated noise intensity resulted in a correspondingly shorter permissible noise exposure duration. The duration of noise exposure from the source varied between 6 and 38 minutes.

The noise propagation pattern extended from the southwest to the northeast, with an intensity of approximately 68-93 dB. The area of highest noise intensity was identified in the vicinity of the crushing plant, specifically in area B, at point B0, located 5 meters from the cone crusher, with an intensity of 92.82 dB. Peak noise levels were recorded at 1 PM, coinciding with the period of maximum operational activity.

The area surrounding the crushing plant, within a radius of 5-35 meters, consistently exhibited noise intensities exceeding 70 dB. Notably, at a distance of 2 meters from the first jaw crusher, the disturbance intensity surpassed the threshold value stipulated by Indonesian national standards.

To mitigate these risks, a comprehensive noise distribution mapping strategy is recommended. This mapping is crucial for the strategic placement of safety signage. Safety signs represent an essential administrative control measure, serving to alert workers to the mandatory use of hearing protection equipment in zones where noise intensity exceeds established quality standards. These findings show the importance of rigorous noise management protocols in industrial settings, particularly in crushing plant operations.

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