



Controlling Noise Levels on the Hearing Health of Mining Workers in the Crushing Plant Area

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Abstract: The mining industry, especially in the crushing plant area, faces serious problems related to noise that can reach more than 85 dB(A). Noise exposure for 8 working hours is at risk of causing temporary or permanent hearing loss (NIHL), which is a common occupational disease found in crushing plant workers. The type of research used in this study is descriptive analytical with a cross-sectional approach. Data collection techniques were carried out by measuring noise levels in the Crushing Plant area and distributing questionnaires to obtain data on the hearing health of mining workers. The location of this study was at CV. Tekad Jaya. The results of the noise level study at CV. Tekad Jaya showed an alarming situation, where 50% of the 14 measurement points exceeded the threshold of 85 dB, with a peak of 96.86 dB at point Std 10. The health impacts were clearly visible with 46.2% of workers experiencing headaches and 61.5% having difficulty communicating, even though the majority had used PPE. The combination of distance and vegetation has proven effective in reducing noise up to 76 dBA at a distance of 95 meters. The metal plate enclosure system showed positive results, reducing noise levels to 83 dBA inside and 67 dBA outside the building. Recommended control strategies include a zoning system with double protection, worker rotation, and health monitoring for areas >85 dBA, and a preventive approach for zones <85 dBA.

Keywords: Crushing Plant; Hearing health; Noise

Introduction

Noise in the mining industry has become a significant occupational health and safety issue in recent decades (Elisabeth et al., 2024). Especially in the crushing plant area, where the rock crushing process produces very high noise levels, the risk of hearing loss in workers is a major concern that requires serious handling (Azman et al., 2022). The crushing plant is a vital facility in mining operations that functions to reduce the size of mining materials to smaller sizes according to the required specifications (Zhang et al., 2023). In the process, the operation of the crusher

machine produces noise levels that can reach 85-95 dB(A), even in some cases it can exceed 100 dB(A), far beyond the recommended safe threshold (Pujianti & Djunaidi, 2022).

Continuous exposure to noise levels above 85 dB(A) for 8 working hours per day can cause temporary or permanent hearing loss (Bohn et al., 2022). Noise-Induced Hearing Loss (NIHL) is one of the most common occupational diseases found in the mining industry, especially in workers in the crushing plant area (Liebenberg et al., 2023). Data from the World Health Organization (WHO) shows that around 466 million people worldwide experience hearing loss, and

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around 16% of them are caused by exposure to noise in the workplace (Alotaibi et al., 2024). In the mining sector itself, research shows that crushing plant workers have a 2-3 times higher risk of hearing loss than workers in other areas (Mandal et al., 2022).

The impact of noise is not only limited to hearing loss, but can also affect the psychological and physiological aspects of workers (Yang et al., 2021). Stress, communication disorders, decreased concentration, and increased blood pressure are some of the side effects often experienced by workers who are continuously exposed to high noise (Themann & Masterson, 2019). Occupational safety and health regulations in various countries have set maximum standards for noise levels allowed in the workplace. In Indonesia, based on the Regulation of the Minister of Manpower and Transmigration Number PER.13/MEN/X/2011, the permissible noise threshold is 85 dB(A) for an exposure time of 8 hours per day (Endrianto, 2023).

Noise control in the crushing plant area is a challenge in itself considering the operational characteristics that do produce high noise levels (Pantelic et al., 2023). A risk control hierarchy approach ranging from elimination, substitution, engineering control, administrative control, to the use of personal protective equipment (PPE) needs to be implemented comprehensively (Orikipete et al., 2024; Söner & Kandemir, 2022). Engineering control efforts such as installing acoustic barriers, routine machine maintenance, and modifying crusher designs can help reduce the noise levels produced (Madahana et al., 2020). However, the implementation of these controls is often hampered by technological limitations and other factors. Administrative controls through work time arrangements, worker rotation, and restricting access to areas with high noise levels are also important strategies in protecting workers' hearing health. A continuous noise monitoring system is needed to ensure the effectiveness of the controls implemented (Chen et al., 2020).

The use of ear protection devices such as ear plugs or ear muffs is a mandatory line of defense (Sherlock et al., 2021). However, the level of worker compliance in using PPE is often a major obstacle in hearing protection efforts (Purwanto, 2024). Therefore, monitoring worker health through regular audiometric examinations is key to early detection of hearing loss. Examination data can be used as a basis for evaluating the effectiveness of the noise control program implemented (Nicholson et al., 2022). The aspect of occupational safety and health culture also plays an important role in the success of a noise control program. Awareness and commitment from all levels of

the organization, from top management to field workers, are needed to create a safe and healthy work environment (Chong et al., 2022).

CV. Tekad Jaya as one of the companies engaged in the processing of mining materials by operating a crushing plant that produces significant noise from the rock breaking process. The noise generated from crushing plant activities has the potential to have a negative impact on the health and safety of workers, especially related to hearing loss due to continuous noise exposure (Mohamed et al., 2021). This problem requires special attention considering that the permissible noise standards have been regulated in laws and regulations to protect workers' health. Monitoring and evaluating noise levels in the work area is very important to ensure compliance with applicable occupational safety and health standards (Yaman et al., 2024).

Noise mapping through isodB (isodecibel) maps is an effective method for understanding noise distribution patterns in work areas (Manwar & Pal, 2022). By knowing the distribution pattern and extent of areas affected by hazardous noise, companies can identify high-risk zones that require special handling (Bozkurt, 2021). This information can also be used as a basis for designing a safer work area layout and determining the need for appropriate personal protective equipment for workers. Given the importance of occupational safety and health aspects, a comprehensive noise control strategy is needed in the crushing plant area (Biały et al., 2021). This strategy can include technical approaches such as machine modifications and soundproofing installations. Implementing the right control strategy will not only protect workers' health but can also improve operational efficiency and create a more conducive work environment (Benson et al., 2024).

Understanding the effects of noise on workers' hearing health is also needed as a basis for developing a comprehensive occupational health prevention and protection program (Themann et al., 2023). Thus, an in-depth study is needed on noise levels, distribution patterns, health impacts, and control strategies that can be applied in the CV Tekad Jaya crushing plant area to create a safe and healthy working environment for workers.

Method

The type of research used in this study is descriptive analytical research with a cross-sectional approach. Data collection techniques are carried out by measuring noise levels in the Crushing Plant area and

distributing questionnaires to obtain hearing health data on mine workers.

The location of the study is at CV. Tekad Jaya. Administratively, it is located in Jorong Bulakan, Tanjung Gadang Village, Lareh Sago Halaban District, Lima Puluh Kota Regency, West Sumatra Province. The location of the study can be seen in the Figure 1.



Figure 1. Map of Research Locations at CV. Tekad Jaya.

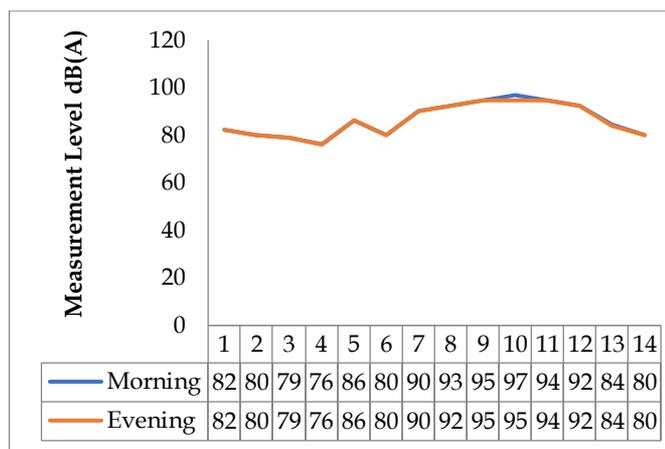
Results and Discussion

Noise Quality Measurement Analysis Results

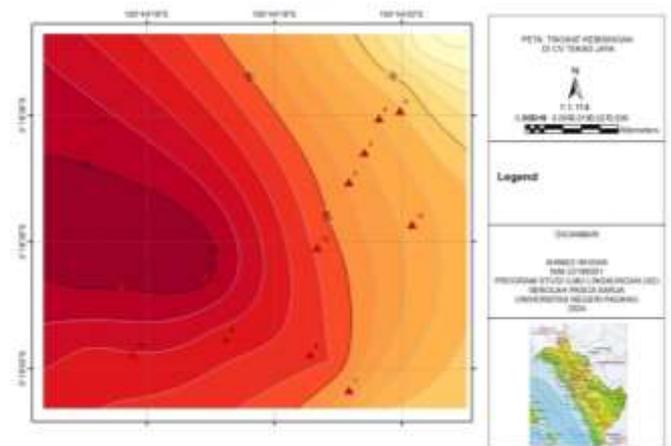
Noise data collection is carried out using a tool in the form of a Sound Level Meter (SLM), at this stage the

sound intensity measurement is carried out in decibels (dB). The process begins with tool calibration to ensure measurement accuracy. Measurements are carried out by holding the SLM at a height of 1.2-1.5 meters from the ground, where the microphone is directed at the sound source at an angle of 70-80 degrees. Reading the noise value on the SLM display is done after the numbers are stable, usually taking 15-30 seconds. Measurements should be carried out several times at the same point to obtain representative data, by recording the time, location, and environmental conditions during the measurement. The data obtained can then be analyzed to determine the average noise level and compared with the applicable quality standards. The noise measurement data can be seen in Figure 2.

From the results of noise measurements at CV. Tekad Jaya and compared with the standard quality standard of 85 dB(A), it was found that out of 14 measurement locations, there were 7 locations (50%) that exceeded the established noise standards. These locations are Std 5, Std 7, Std 8, Std 9, Std 10, Std 11, and Std 12, with the highest noise level recorded at Std 10 reaching 96.86 dB in the morning and 96.77 dB in the afternoon, exceeding the standard by 11.86 dB and 11.77 dB. This indicates that the area is critical and requires special control.



(a)



(b)

Figure 2. The noise measurement data: (a) Noise Level Measurement Results; and (b) IsodBA (isodecibel) map

Meanwhile, the other 7 locations, namely Std 1, Std 2, Std 3, Std 4, Std 6, Std 13, and Std 14 are still within the safe limit below the standard of 85 dB(A). The lowest noise level was found at point Std 4 with an average of 76.16 dB in the morning and 76.07 dB in the afternoon, which means it is 8.84 dB and 8.93 dB below the established standard. This shows a significant

variation in noise levels between measurement locations.

Noise Safe Distance

Noise safety distance is an important aspect of occupational health and safety. Noise levels are measured in decibels (dB), and exposure to excessive

noise can cause various health problems, especially hearing loss (Mahardika et al., 2024). The following is a picture of the noise level and distance ratio in the open area of CV. Tekad Jaya.

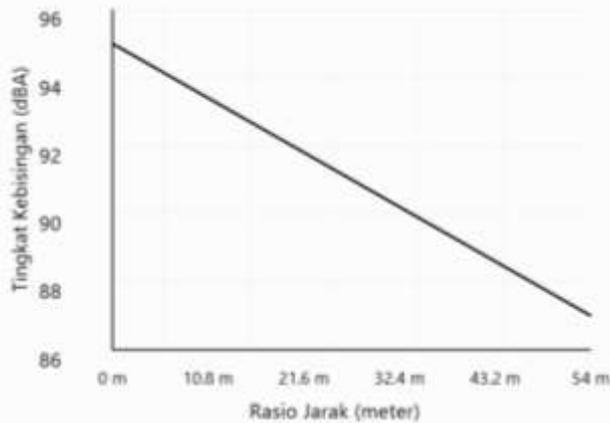


Figure 3. Noise Levels in Open Areas

Based on the graph shown, there is an inverse relationship between noise level (La-Lb in dBA) and distance ratio (b/a) in open areas. The graph shows a decrease in noise level as the distance ratio increases. At the starting point (distance ratio 0 m), the noise level reaches around 96 dBA, which is quite high and has the potential to harm hearing if exposed for a long time. As the distance ratio increases, there is a relatively consistent decrease in noise level. At a distance ratio of 10.8, the noise level drops to around 94 dBA, and continues to decrease until it reaches around 92 dBA at a distance ratio of 21.6 m.

The decrease continues until the maximum distance ratio shown in the graph (54 m), where the noise level reaches its lowest point of about 86 dBA. This shows that distance plays a significant role in reducing noise intensity in open areas, where each additional distance will result in a measurable reduction in noise level. The decreasing pattern shown in the graph is in accordance with the principle of sound propagation in open areas, where sound intensity decreases with increasing distance from the sound source. In addition, the decrease in noise level can also be influenced by cover factors. One of the covers that can affect noise levels is trees.

Trees play an important role in reducing noise levels in the surrounding environment through several natural mechanisms. Leaves, branches, and twigs on trees can scatter and absorb sound waves that pass through them, thereby reducing the intensity of noise that reaches the area behind the rows of trees. The denser and thicker the vegetation cover, the more effective its ability to dampen sound (Melanira & Rudianto, 2023). The following is a picture of the noise

level and distance ratio in the area with cover at CV. Tekad Jaya.

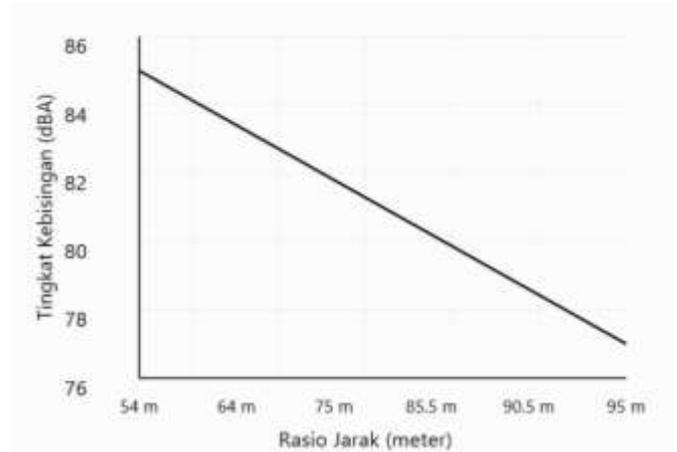


Figure 4. Noise Levels in Covered Areas

Based on the graph above, the graph shows a linear and consistent downward trend, where the highest noise level was recorded at around 86 dBA at a distance ratio of 54 m, then experienced a gradual decrease to reach around 76 dBA at a distance ratio of 95 m. This decrease indicates that the greater the distance ratio between the measurement points, the lower the measured noise level. This shows the effectiveness of the cover in reducing noise, where each additional distance has a relatively constant impact on reducing noise levels.

Based on the graph, it can be seen that there is a relationship between the distance ratio and the noise level which is proportional, where each increase in the distance ratio will be followed by a decrease in the noise level. Overall, the cover in the area plays an effective role in reducing noise levels as the distance increases.

Noise Level Questionnaire Results

The questionnaire on hearing complaints of workers in the crushing plant area is an important instrument in monitoring and evaluating workers' health. The crushing plant area is known as a work environment with high noise levels, considering the process of breaking rocks that produces loud sounds. In this case, the questionnaire was designed to collect information on the history of noise exposure, hearing complaints, and symptoms that workers may have experienced. The results of the questionnaire can be seen in Table 1.

Based on the questionnaire results in Table 1, it can be seen that in terms of hearing complaints, the majority of respondents (76.9%) did not feel pain or discomfort in their hearing during or after work. However, there are indications of health problems that

need to be considered where as many as (46.2%) respondents experienced headaches during work. However, the history of serious hearing loss is

relatively low, with only as many as (3.8%) respondents having undergone hearing surgery or experiencing hearing infections.

Table 1.Frequency Distribution of Hearing Complaints of Mine Workers at CV. Tekad Jaya.

Question	Yes		No	
	f	%	f	%
Do you often feel pain or discomfort in your hearing during or after work?	6	23.1	20	76.9
Do you experience headaches while working?	12	46.2	14	53.8
Have you ever used a hearing aid while working?	9	34.6	17	65.4
Do you feel a buzzing sound in your hearing?	5	19.2	21	80.8
Do you find it difficult to focus while working or after work?	3	11.1	24	88.9
Have you ever had hearing surgery before?	1	3.8	25	96.2
Are you able to hear and understand what the speaker is saying without seeing his/her face from across a quiet room when speaking normally?	19	73.1	7	26.9
Have you ever experienced an infection or hearing loss?	1	3.8	25	96.2
Have you ever experienced difficulties communicating while working?	13	50	13	50
Have you ever felt irritation in your hearing due to noise at work?	2	7.7	24	92.3
Have you ever had difficulty sleeping due to ringing in your ears?	3	11.5	23	88.5
Do you use Personal Protective Equipment (PPE) against noise while working?	20	76.9	6	23.1
Do you often work extra hours outside your usual shift?	21	80.8	5	19.2
Do you feel that noise makes it difficult to concentrate while working?	11	42.3	15	57.7
Do you feel that noise makes it difficult to communicate with fellow workers?	16	61.5	10	38.5

Recommendations for Noise Level Control Technology and Methods

In an effort to control noise in mining, various control technologies can be implemented. The use of an enclosure in the form of an iron plate used on a stone crusher machine is one effective solution to reduce noise. The iron plate is chosen as the enclosure material

because it has a high density so that it is effective in reflecting and absorbing sound energy produced by the stone crusher machine (Khalik & Hermawanto, 2019). The layout design of the stone crusher machine cover using iron plates can be seen in Figure 5.

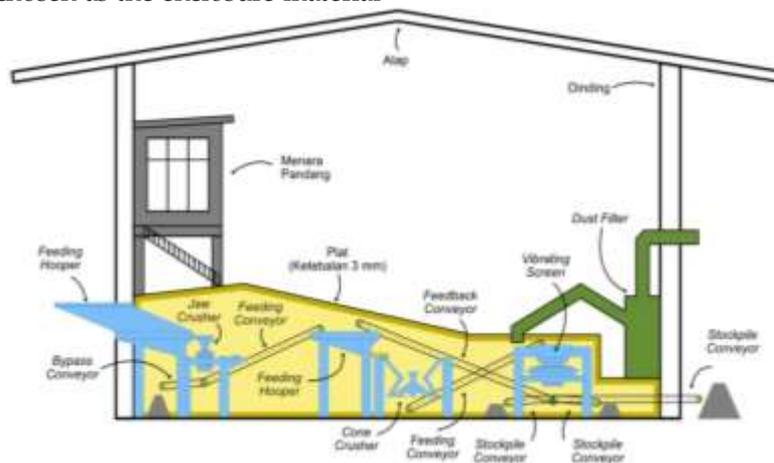


Figure 5. Stone Crusher Machine Cover Design Using Iron Plate.

Based on the image above, the design of the stone crusher machine uses a closed building structure consisting of walls and a roof. This design shows a comprehensive approach to noise control by closing the entire series of stone crushing processes using a stone crusher machine, from the feeding hopper to the stockpile conveyor in one closed room.

Implementation of noise control technology in mining areas requires a comprehensive and effective

solution. One innovation that has been successfully implemented is the use of an enclosure system with iron plates on the stone crusher machine, as designed by PT. Semen Padang. This design has been proven to be able to reduce noise levels below the normal noise threshold of 85 dBA, according to work safety standards.

The noise level generated at PT. Semen Padang shows significant variation between the inside and

outside areas of the building. Inside the building, the noise level was recorded at 83 dBA, while outside the building it reached 67 dBA. Although the noise level inside the building is higher, it is still below the normal noise threshold set in the occupational safety standards, which is 85 dBA. This shows that the noise control implemented by the company has succeeded in maintaining the level of sound exposure at a safe level for workers.

The successful implementation of this enclosure system is clear evidence that noise control technology innovation can provide an effective solution in overcoming the problem of noise exposure in the

mining industry environment (Saputra & Rahmawati, 2025). The measurement results showing a noise level of 83 dBA inside the building and 67 dBA outside the building indicate that this system has succeeded in creating a safer and more comfortable working environment for workers, while meeting applicable occupational safety standards.

In addition to the technology recommendations offered, there are also SOPs (Standard Operating Procedures) that must be followed by workers working in areas with relatively high noise levels. The SOPs for workers that are differentiated according to distance and noise levels can be seen in Table 2.

Table 2. SOP (Standard Operating Procedure) for Workers according to distance and noise level.

Zone	Distance (m)	Noise Level	SOP (Standard Operating Procedure) Used
Above 85 dBA	0-54 m	96-86 (dBA)	<ol style="list-style-type: none"> 1. It is mandatory to use double protection (a combination of earmuff and earplug) 2. Limit maximum exposure time to 1-8 hours 3. Worker rotation every 1-2 hours 4. Install warning lights and extreme noise hazard alarms 5. Audiometry examination every 3-6 months 6. Only workers may enter
Under 85 dBA	54-95 m	84-76 (dBA)	<ol style="list-style-type: none"> 1. Use of earplugs is recommended (not mandatory) 2. There is no specific time limit 3. Provide PPE for those in need 4. Noise impact education 5. Annual health check 6. The area is permitted for visitors to enter

Based on the above data, there are significant variations in noise control at various measurement distances. In the closest zone (0-54 meters) with a noise level of 96-86 dBA, strict control is required including the use of double protection (a combination of earmuffs and earplugs), exposure time restrictions, worker rotation systems, and routine audiometric examinations. The strictest level of control is applied at a distance of 0 meters (96 dBA) with a maximum exposure limit of 1 hour and rotation every 45 minutes, then gradually decreases as the distance increases and the noise level decreases.

For zones with longer distances (64-95 meters) and noise levels of 84-76 dBA, a lower to minimal control approach is applied. In this range, the use of PPE is optional to not required, but is still accompanied by periodic noise monitoring and routine health checks. K3 education and socialization programs are the main focus, with an emphasis on consistent monitoring of the work environment to ensure there is no significant increase in noise risk. The implementation of SOPs and the use of different PPE in each zone reflect a tiered risk control approach that allows for optimization of worker protection according to the level of exposure faced.

Discussion

Based on the results of the research conducted at CV. Tekad Jaya, quite worrying conditions were found related to noise levels in the work area. Of the total 14 measurement points, 50% of the locations showed noise levels that exceeded the established quality standard of 85 dB. These critical points were identified at Std 5, Std 7, Std 8, Std 9, Std 10, Std 11, and Std 12, with the highest noise levels reaching 96.86 dB in the morning and 96.77 dB in the afternoon at point Std 10. This condition indicates the potential for significant health risks for workers who work in these areas.

The study also revealed a clear relationship between distance and noise level, where the further the distance from the noise source, the lower the measured noise level. In open areas, there was a decrease in noise from 96 dBA at the source point to 86 dBA at a distance of 54 meters. This decrease was more significant in areas with cover, where noise levels could reach 76 dBA at a distance of 95 meters. This proves that the combination of distance and vegetation cover provides a more optimal noise reduction effect compared to the distance factor alone (Hamidun et al., 2021).

In terms of impact on workers, the questionnaire results showed interesting findings. Although 76.9% of

workers did not report any direct hearing discomfort, there were indications of secondary health problems with 46.2% of workers experiencing headaches during work. Communication problems were also a significant issue, with 61.5% of workers reporting difficulty communicating with coworkers and 50% experiencing difficulty communicating while working. However, the level of awareness of the use of PPE was quite good, as indicated by 76.9% of workers using personal protective equipment against noise.

In an effort to control noise, the implementation of an enclosure system using iron plates, as has been implemented at PT. Semen Padang, shows promising results. This system is able to reduce noise levels by up to 83 dBA inside the building and 67 dBA outside the building. This proves that engineering control solutions can be effective in controlling noise exposure in the work area. The success of this implementation can be a reference for CV. Tekad Jaya in developing a similar noise control system (Saefudin & Emra, 2021).

Based on the research results, a zoning-based control strategy is recommended as a comprehensive approach to addressing noise issues. For zones with noise levels above 85 dBA (distance 0-54m), strict control is required including the use of mandatory double protection, exposure time restrictions, worker rotation systems, and intensive health monitoring. Meanwhile, for zones with noise levels below 85 dBA (distance 54-95m), a lighter approach can be applied, such as the use of optional PPE with a focus on education and monitoring as well as periodic health checks.

As a follow-up to this study, several recommendations for improvement can be implemented. First, it is necessary to implement an enclosure system in areas with the highest noise levels, especially at Std 10 and its surroundings. Second, develop a more structured worker rotation program to minimize excessive noise exposure. Third, improve worker health monitoring programs, especially for those working in zones with noise above 85 dBA. Fourth, optimize the layout of vegetation as a natural barrier to increase the effectiveness of noise reduction. Finally, evaluate and improve the communication system in the work area to address communication problems reported by workers. The comprehensive implementation of these recommendations is expected to improve work safety and comfort at CV. Tekad Jaya, while meeting applicable work safety standards.

Conclusion

Based on the results of the noise level study at CV. Tekad Jaya, it can be concluded that from 14

measurement points, 50% of the locations exceeded the noise quality standard of 85 dB, with the highest level reaching 96.86 dB at Std 10. There is a negative correlation between distance and noise level, where the combination of distance and vegetation cover provides an optimal noise reduction effect, reducing the level to 76 dBA at a distance of 95 meters. The questionnaire results showed that 46.2% of workers experienced headaches and 61.5% had difficulty communicating, although 76.9% had used PPE. The implementation of an enclosure system with iron plates has been proven effective in reducing noise to 83 dBA inside and 67 dBA outside the building as has been done by PT. Semen Padang. A zoning-based control strategy with the use of double protection, worker rotation, and health monitoring is recommended for zones >85 dBA, while zones <85 dBA require a lighter approach with a focus on education and regular monitoring.

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Author Contribution

A. I: preparation of the original draft, results, discussion, methodology, conclusion; M. G, E. B, N. S and M. S: analysis, review, proofreading and editing.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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