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Analysis of Noise Level Measurement and Mapping Using the Surfer Application at PT. PLN (Persero) ULPLTD Labuhan

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ABSTRACT

Noise is a physical factor in the work environment that may cause health problems when it exceeds the permissible threshold. PT. PLN (Persero) ULPLTD Labuhan, a diesel power plant unit, generates continuous noise from diesel engines and supporting equipment. This study aimed to determine the noise level at each measurement point and to analyze the spatial distribution of noise using the Surfer application. A quantitative descriptive method was applied, with measurements taken at seven points using a Sound Level Meter for 10 minutes at each point. Data were processed into Equivalent Continuous Noise Level (Leq) values and mapped in Surfer using the Inverse Distance Weighting (IDW) interpolation method. Results showed noise levels ranging from 58.1 to 69.3 dBA, with the highest value in the warehouse area and the lowest in the northern residential area. The noise map indicated that operational areas experienced higher noise exposure than residential areas, forming a decreasing gradient toward the surrounding residential zone. Noise levels in the work area remained below the 85 dBA occupational threshold, whereas the surrounding residential areas exceeded the 55 dBA environmental quality standard, indicating that distance and building layout influence the spatial pattern of noise exposure around the plant.

Keywords: *Noise, Noise Mapping, Sound Level Meter, Spatial Distribution, Surfer.*

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1. | INTRODUCTION

Noise is one of the physical hazards commonly encountered in industrial environments, particularly in diesel power generation units (PLTD), where diesel engines, generators, compressors, cooling systems, and other supporting equipment operate continuously. These machines produce high sound pressure levels that may exceed occupational exposure limits and pose significant health risks to workers. Continuous exposure to excessive noise has been identified as one of the major occupational hazards because it not only affects auditory function but also influences workers' physiological and psychological conditions. Exposure to noise exceeding the Threshold Limit Value (TLV) can result in permanent hearing impairment or Noise-Induced Hearing Loss (NIHL), reduced work concentration, communication difficulties, increased stress, fatigue, sleep disturbance, and a higher probability of occupational accidents (Tobing et al., 2024). Recent reviews also indicate that occupational noise remains one of the leading causes of preventable hearing disorders worldwide despite advances in hearing conservation programs and engineering controls (Salam et al., 2024; Kanu et al., 2025). Furthermore, prolonged exposure to industrial noise has been associated with adverse cardiovascular, cognitive, and psychological effects, emphasizing the importance of comprehensive workplace noise management (SheikhMozafari et al., 2025). In addition to workers, residents living around industrial facilities may also experience environmental impacts, including continuous noise pollution generated by industrial operations, which can reduce environmental quality and community comfort (Ambarwati et al., 2023).

According to the Regulation of the Minister of Manpower of the Republic of Indonesia Number 5 of 2018, the maximum permissible occupational noise exposure is 85 dBA for an 8-hour working day. Noise levels exceeding this limit require the implementation of engineering controls, administrative controls, and personal protective equipment such as hearing protectors to minimize workers' exposure. Compliance with occupational noise standards is essential because effective noise control contributes not only to worker health protection but also to improved productivity, communication efficiency, and operational safety. Therefore, routine monitoring and evaluation of workplace noise are indispensable components of occupational health and safety management systems in industrial facilities.

PT. PLN (Persero) ULPLTD Labuhan is a diesel power generation unit that operates intensively to maintain the continuity of electricity supply. The generating machines are positioned relatively close to operational work areas and operator control rooms, causing workers to experience continuous exposure to machine-generated noise throughout daily operations. In addition, the building configuration, which is partially enclosed, together with concrete walls, steel structures, and hard floor surfaces, promotes sound reflection and reverberation that may increase overall noise intensity. Beyond occupational exposure, residents living around the power plant may also experience environmental noise generated by continuous machine operations. Environmental noise has increasingly become an important issue because prolonged exposure may reduce community comfort and quality of life, especially in residential areas located near industrial facilities (Matalapu et al., 2025). Similar findings have been reported in several diesel power plants where industrial operations contributed significantly to elevated environmental noise levels in adjacent residential zones (Anggraini et al., 2021).

Conventionally, workplace noise is measured using a Sound Level Meter (SLM), which provides accurate sound pressure measurements at individual sampling points. However, point measurements alone are insufficient to represent the spatial variability of noise throughout an industrial facility because noise propagation is influenced by multiple factors, including machine arrangement, building geometry, operational conditions, and surface reflection characteristics. Consequently, the integration of measurement data with spatial analysis has become increasingly important for identifying the distribution of occupational and environmental noise. Industrial noise mapping has been widely recognized as an effective approach for visualizing spatial noise distribution, supporting environmental planning, and developing appropriate mitigation strategies (Putro et al., 2023). In recent years, geographic interpolation techniques have been extensively applied to estimate sound levels between measurement locations and produce continuous noise contour maps that facilitate the identification of high-risk exposure zones.

Among various interpolation techniques, the Inverse Distance Weighting (IDW) method has been widely used because it assumes that neighboring observation points exhibit more similar characteristics than distant points. This approach enables the generation of representative spatial distributions from discrete measurement data and has demonstrated satisfactory performance in industrial and environmental noise studies (Putro et al., 2023). The resulting contour maps provide important information for determining safe working zones, identifying areas requiring engineering noise control, optimizing worker movement, and evaluating the potential impact of industrial activities on surrounding communities. Similar spatial mapping approaches have also been successfully implemented in several diesel power plants in Indonesia, demonstrating their effectiveness for occupational and environmental noise assessment (Huda et al., 2022; Matalapu et al., 2025).

In addition to spatial visualization, comprehensive noise assessment requires statistical descriptors capable of representing both average and fluctuating acoustic conditions. Statistical parameters such as Equivalent Continuous Noise Level (Leq), L90, L50, L10, and L1 provide valuable information regarding background noise, median noise levels, peak noise events, and temporal variability. The integration of these statistical indicators with spatial interpolation offers a more comprehensive evaluation than conventional point-based measurements alone because it combines quantitative assessment with geographical visualization of exposure patterns.

Therefore, this study aims to determine the noise level at each measurement point and analyze the spatial distribution pattern of noise using the Surfer application at PT. PLN (Persero) ULPLTD Labuhan. The novelty of this study lies in the integration of statistical noise analysis (Leq, L90, L50, L10, and L1) with spatial mapping based on the Inverse Distance Weighting (IDW) interpolation method in the Surfer application, enabling a comprehensive evaluation of noise distribution patterns between operational work areas and surrounding residential zones. The findings are expected to provide scientific evidence for occupational health protection, environmental noise management, and the development of more effective engineering control strategies within diesel power generation facilities.

2. | RESEARCH METHOD

This study was conducted at PT. PLN (Persero) ULPLTD Labuhan over a two-month period from January to February 2026. The research employed both primary and secondary data. Primary data consisted of environmental noise measurements collected at seven observation points using a calibrated LUTRON SL-4022 Sound Level Meter (SLM) and the geographical coordinates (X and Y) of each measurement location obtained using a Global Positioning System (GPS). Secondary data included applicable occupational and environmental noise regulations, specifically the Regulation of the Minister of Manpower of the Republic of Indonesia Number 5 of 2018 concerning Occupational Safety and Health in the Work Environment and the Decree of the Minister of State for the Environment Number 48 of 1996 concerning Environmental Noise Standards. Additional supporting information, including the layout map of ULPLTD Labuhan and relevant scientific literature on industrial noise and spatial interpolation, was also utilized.

Noise measurements were performed systematically at seven locations selected based on the proximity to major noise sources and the intensity of worker activities. The observation points consisted of Point 1 (Muster Point), Point 2 (Office Area), Point 3 (Laundry Area), Point 4 (Warehouse), Point 5 (Workshop), Point 6 (West Residential Area), and Point 7 (North Residential Area). During each measurement, the SLM microphone was mounted on a tripod approximately 1.5 m above the ground surface and oriented toward the dominant noise source. Measurements were conducted using the A-weighting network with the Fast response mode, following international environmental noise measurement practices. Each observation lasted 10 minutes within each designated monitoring period and was repeated continuously over a 24-hour cycle divided into seven observation intervals to represent variations in daily operational activities.

The recorded noise data were processed using Microsoft Excel to determine the maximum (Lmax) and minimum (Lmin) sound pressure levels for each observation period. Frequency distribution analysis was subsequently performed to calculate the statistical noise descriptors L90, L50, L10, and L1 following the procedure described by Balirante et al. (2020). The equivalent continuous sound level (Leq) was calculated as the primary indicator for evaluating overall noise exposure. The Leq values obtained at Points 1–5 were compared with the occupational exposure limit of 85 dBA specified in the Regulation of the Minister of Manpower Number 5 of 2018, whereas the values at Points 6 and 7 were evaluated against the residential environmental noise standard of 55 dBA established in the Decree of the Minister of State for the Environment Number 48 of 1996.

Finally, the coordinate data (X and Y) together with the corresponding Leq values (Z) were imported into the Surfer software for spatial analysis. Noise distribution was generated using the Gridding function with the Inverse Distance Weighting (IDW) interpolation method, which estimates unknown values based on the assumption that nearby measurement points have greater similarity than more distant points. The interpolation results were visualized as contour maps illustrating the spatial distribution of noise across the study area. These maps were subsequently used to identify high-noise and low-noise zones, providing a comprehensive basis for evaluating occupational noise exposure and the potential impact of industrial activities on surrounding residential areas.

3. | RESULTS AND DISCUSSION

Measurements were carried out at seven points representing operational areas and residential areas around PT. PLN (Persero) ULPLTD Labuhan. The equivalent noise level (Leq) values at each measurement point, along with their comparison to the applicable Threshold Value (NAV), are presented in Table 1.

Table 1. Leq Value and Threshold Value (NAV) Comparison at Each Measurement Point

Dot	Location	Leq (dBA)	Reference Regulation	NAB (dBA)	Status
1	Muster Point	64,7	Permenaker 5/2018	85	Secure
2	Office Area	67,2	Permenaker 5/2018	85	Secure
3	Laundry Area	68,6	Permenaker 5/2018	85	Secure
4	Warehouse	69,3	Permenaker 5/2018	85	Secure
5	Workshop	69,2	Permenaker 5/2018	85	Secure
6	West Side Settlement	63,7	Ministry of Agriculture and Forestry 48/1996	55	Beyond

Dot	Location	Leq (dBA)	Reference Regulation	NAB (dBA)	Status
7	North Side Settlement	58,1	Ministry of Agriculture and Forestry 48/1996	55	Beyond

Based on Table 1, the highest noise level was obtained at Point 4 Warehouse of 69.3 dBA, followed by Point 5 of the Workshop of 69.2 dBA and Point 3 of the Washing Area of 68.6 dBA. The high noise value at these three points is influenced by their proximity to the generating unit (Allen and Deutz machines), radiator cooling fans, as well as operational activities such as loading and unloading, component washing, and workshop work that takes place continuously. The noise value at Point 1 to Point 5 as a whole is still below the work noise NAV of 85 dBA based on Permenaker Number 5 of 2018 so that it is categorized as safe for workers.

Different conditions were found at Point 6 of the West Side Settlement and Point 7 of the North Side Settlement with Leq values of 63.7 dBA and 58.1 dBA, respectively. This value has exceeded the standard noise level of residential environments by 55 dBA based on the Ministry of Environment Number 48 of 1996, or exceeded the quality standards of 8.7 dBA and 3.1 dBA. The decrease in noise value from Point 6 to Point 7 indicates the influence of distance on the attenuation of noise intensity, in line with the findings of Fanani and Hajar (2025) on PLTD Pangkalan Batang who reported a reduction in noise from 72.54 dBA at a radius of 20 meters to 57.16 dBA at a radius of 120 meters from the source.

Noise Scatter Mapping

The coordinate data and Leq values at the seven measurement points were interpolated using the Inverse Distance Weighting (IDW) on the Surfer app to generate a contour map of the noise distribution, as shown in Figure 1.

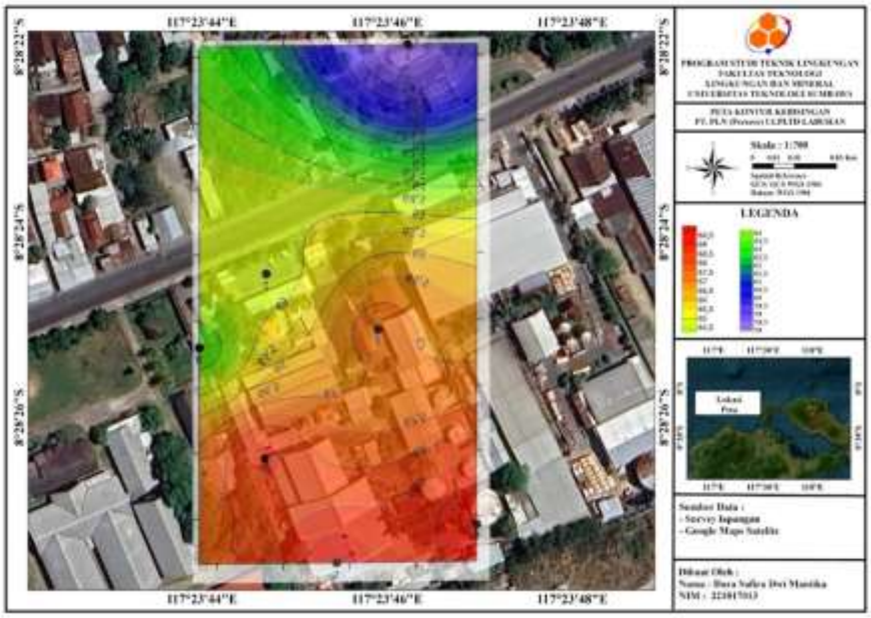

Figure 1. Contour map of the noise level distribution as a result of IDW interpolation using the Surfer application at PT. PLN (Persero) ULPLTD Labuhan.

The mapping results show that the noise level forms a gradient pattern that decreases from the plant's operational area to the residential area on the north side. The zones with the highest noise levels (68-69.5 dBA) are concentrated at Points 3, 4, and 5, which are directly adjacent to the main noise sources in the form of diesel engines, generators, radiators, and supporting equipment operating simultaneously. This pattern is in line with the results of Tobing et al. (2024) research on the Kahayan Baru PLTD, which shows that the area adjacent to the generating machine has the highest noise level and decreases at locations that are further away from the source.

The asymmetrical contour indicates that noise distribution is influenced not only by distance to the source but also by the physical conditions of the environment and building layout. The presence of buildings, boundary walls, vegetation, and open spaces around the site can cause reflection, absorption, and diffraction of sound waves, resulting in uneven noise distribution (Yan et al., 2022; Sarul, 2025). This condition indicates that the characteristics of the surrounding environment play a significant role in determining the noise level received at each observation point. Therefore, noise control efforts need to consider spatial aspects and the physical elements of the area in addition to noise reduction at the source (Hemmat et al., 2023).

The presence of warehouse buildings, workshops, and supporting facilities is suspected to act as partial barriers that influence the direction of sound wave propagation, resulting in differences in noise levels between Points 6 and 7, even though both are relatively close to the main source. Overall, the mapping results confirm that noise levels in the Labuhan ULPLTD operational area still meet the Occupational Noise Threshold Value, but noise levels received by surrounding residential areas have exceeded applicable environmental quality standards. Therefore, this spatial distribution pattern provides important information for understanding the risk of noise exposure around the power plant.

These conditions demonstrate the need for a disturbance management approach that focuses not only on occupational safety aspects but also on the environmental quality around the power plant. Therefore, the results of this mapping can be used as a basis for developing disturbance management strategies, such as optimizing equipment layout, installing acoustic barriers along sound transmission paths, and developing green zones as natural dampers. These measures are expected to mitigate the impact of disturbances on the community without disrupting the operational effectiveness of the power plant.

4. | CONCLUSION

The noise level at the seven measurement points at PT. PLN (Persero) ULPLTD Labuhan varies between 58.1-69.3 dBA, with the highest value in the Warehouse and the lowest value in the residential area on the north side. All points in the operational area still meet the Work Noise Threshold Value of 85 dBA based on Permenaker Number 5 of 2018, while the two points in residential areas have exceeded the standard environmental noise level of 55 dBA based on the Ministry of Environment Number 48 of 1996. The mapping results using the IDW interpolation method in the Surfer application show a noise distribution pattern that forms a descending gradient from the plant's operational area to the residential area, with the highest noise zone concentrated in the Washing Area, Warehouse, and Workshop due to its proximity to the main noise source, as well as lower noise zones in residential areas which are affected by the distance and layout of the building as a partial barrier to sound propagation. The distribution pattern emphasizes that although the occupational safety and health aspects in the operational area are still met, the impact of noise on the surrounding residential areas still needs attention.

The implications of this research indicate that spatial mapping of disturbances can serve as a basis for PT. PLN (Persero) ULPLTD Labuhan and the local government in formulating more effective disturbance control strategies. Mitigation efforts can include installing noise barriers, improving machine maintenance, rearranging the layout of disturbance sources, adding vegetation as a natural dampener, and implementing regular disturbance monitoring, especially in areas directly adjacent to the plant. Furthermore, the results of this study can serve as a reference in developing environmental management policies to minimize potential health and comfort disruptions to communities near the power plant.

Further research is recommended to expand the scope of measurements by considering variations in operating hours, meteorological conditions such as wind direction and speed, and topographic factors that influence the distribution of disturbances. Future research could also integrate analysis of public perception of disturbance levels, spatial modeling using other interpolation methods or GIS-based software, and evaluation of the effectiveness of various disturbance mitigation scenarios to produce more comprehensive and sustainable environmental management recommendations.

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The authors declare that there is no conflict of interest.

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Data Disclosure Statement
The data that support the findings of this study are available from the corresponding author upon reasonable request.

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