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Geospatial Analysis Of Noise Pollution From Power Plant Operations In Urban Residential Areas: A Study of PLTD Telaga, Gorontalo Province

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ABSTRAK

Seiring dengan pertumbuhan populasi dan urbanisasi yang pesat, kebisingan telah menjadi masalah serius yang terus dalam lingkungan pemukiman perkotaan. Berbagai aktivitas manusia seperti transportasi, konstruksi, industri, serta kegiatan komersial berkontribusi signifikan terhadap kebisingan. Penelitian ini bertujuan untuk menganalisis tingkat kebisingan yang dihasilkan oleh Pembangkit Listrik Tenaga Diesel (PLTD) Telaga, Provinsi Gorontalo, serta distribusinya pada area pemukiman di sekitarnya menggunakan pendekatan geospasial. Kebisingan dari operasional PLTD Telaga berpotensi memberikan dampak negatif pada kualitas hidup masyarakat, terutama terkait gangguan kesehatan fisik dan mental. Penelitian ini menggabungkan metode pengukuran kebisingan dengan analisis spasial berbasis Sistem Informasi Geografis (SIG) untuk memetakan distribusi kebisingan. Pengukuran dilakukan pada berbagai titik di sekitar PLTD dan pemukiman dengan menggunakan *Sound Level Meter*. Data yang dikumpulkan dianalisis untuk mengetahui tingkat kebisingan pada waktu beban normal dan beban puncak. Hasil penelitian menunjukkan bahwa tingkat kebisingan di area kerja PLTD secara signifikan melebihi ambang batas yang diperbolehkan, yaitu mencapai 109-110 dBA, sementara kebisingan di area pemukiman bervariasi antara 50-77 dBA. Hasil analisis spasial menunjukkan bahwa distribusi kebisingan tertinggi berada di area sekitar mesin PLTD dan sebagian kecil area pemukiman terdekat. Temuan ini menunjukkan perlunya tindakan mitigasi seperti pengaturan jam kerja, penggunaan alat pelindung diri (APD), dan perbaikan tata ruang untuk mengurangi dampak kebisingan terhadap masyarakat sekitar. Penelitian ini diharapkan dapat menjadi acuan dalam perencanaan tata ruang kota dan pengelolaan lingkungan yang lebih baik di sekitar area PLTD Telaga.

Kata Kunci: Kebisingan, PLTD Telaga, Geospasial

ABSTRACT

Along with population growth and rapid urbanization, noise has become a persistent serious problem in urban residential environments. Various human activities such as transportation, construction, industry, as well as commercial activities contribute significantly to noise. This research aimed to analyze the noise level generated by the Telaga Diesel Power Plant (PLTD), Gorontalo Province, and its distribution in the surrounding residential areas using a geospatial approach. Noise from the operation of PLTD Telaga has the potential to have a negative impact on people's quality of life, especially related to physical and mental health problems. This research combined noise measurement method with Geographic Information System (GIS)-based spatial analysis to map the noise distribution. Measurements were carried out at various points around the PLTD and settlements using a Sound Level Meter. The data collected was analyzed to determine the noise level at Normal Load and Peak Load times. The results showed *that the noise level in the PLTD work area significantly exceeded the allowable threshold, reaching 109-110 dBA, while the noise in residential areas varied between 50-77dBA. The results of spatial analysis showed that the highest noise distribution was in the area around the PLTD engine and a small part of the nearby residential area. These findings indicate the need for mitigation measures such as setting working hours, using personal protective equipment (PPE), and improving spatial planning to reduce the impact of noise on the surrounding community. This research is expected to serve as a reference in urban spatial planning and better environmental management around the Telaga PLTD area..*

Keywords: *Noise, Telaga Diesel Power Plant, Geospatial.*

INTRODUCTION

Urban noise has become a serious problem that continues to increase with population growth and rapid urbanization. In many big cities, noise problem is considered as a growing problem among the people (Olaide., 2013). Various human activities such as transportation, construction, industry, and commercial activities contribute significantly to noise. Environmental noise is one of the main challenges in maintaining the quality of life in urban areas, especially around industrial facilities such as diesel power plants. Power plant activities, especially those using diesel-fueled engines, often generate significant levels of noise, which can have a direct impact on the physical and mental health of people living nearby (Adriyani, 2017; Ella Anastasya Sinambela & Mardikaningsih, 2022).

The most striking activity in the city center related to the use of machines that cause enough noise is the Telaga Diesel Power Plant (PLTD), which is located in an urban area where people do their activities, both as a place to live and work. This machine activity, of course, causes quite high noise, considering that the engine used is classified into a large enough engine, as well as engine activity that lasts all day without stopping. PLTD Telaga, located in the city of Gorontalo, is one of the important energy sources in the area. However, the operation of this power plant is also a source of noise that can affect the quality of life of residents in adjacent settlements.

Prolonged noise can have an impact on workers and the community around PLTD Telaga, especially if it exceeds the permitted threshold, which can cause various health problems such as hearing loss, increased blood pressure, and sleep disturbances (Adriyani, 2017; Wardani et al., 2020). Research by Rahman shows that residents living in noisy environments report a higher incidence of health problems such as insomnia, stress, and cardiovascular problems. This is particularly concerning in urban residential areas near power plants, where noise can significantly affect quality of life (Rahman et al., 2022a). In addition to PLTD Telaga, around the area there are also several small industries that can cause noise, such as the bike-assembly workshop located in the western part of PLTD Telaga, next to the PLTD Telaga. To the north and east, there is a five-way junction road that connects the Trans Sulawesi route, which is one of the congested areas in Gorontalo Province, and Terminal 42 Andalas, which is always crowded with public transportation vehicles. Thus, the noise that occurs in this area becomes quite complex and requires a comprehensive understanding of noise sources.

The integration of Geospatial Information Systems (GIS) in monitoring and analyzing Noise provides a powerful framework for understanding spatial distribution and temporal variation, which is critical for effective urban planning and public health interventions. GIS technology has proven to be a very helpful tool in environmental noise assessment (Mihalache et al., 2023). This technology facilitates the collection, analysis and visualization of spatial data, allowing researchers to create more detailed noise maps by depicting the intensity and distribution of noise in different urban areas (Othman et al., 2024). For example, research conducted by Olaide (2013), emphasized the effectiveness of GIS in managing environmental pollution, highlighting its role in collecting and analyzing spatial information (Olaide., 2013). This capability is essential for identifying noise hotspots and understanding the relationship between noise levels and residential areas. Similarly, research by Yao (2013) explains how noise mapping can increase public awareness of noise and aid urban planning efforts, thus emphasizing the importance of geospatial analysis in addressing this issue (Yao et al., 2013).

Specific sources of noise from power plants can vary widely, depending on the type of facility and its operational processes. In 2013, Orkomi conducted an analysis of noise in a cement plant, identifying crushing units as the main source of noise (Ahmadi Orkomi et al., 2013). These findings are relevant to power plants, where heavy machinery and equipment can generate significant noise levels. In addition, the temporal pattern of noise, such as noise peaks during operational hours, can be critical to understanding its impact on the surrounding community. Gheibi (2022), found that noise levels were highest at night, which suggests that the timing of power plant operations may intensify the impacts experienced by residents (Gheibi et al., 2022).

Noise analysis has undergone significant development by utilizing modern tools and techniques to measure and assess its impact on the environment. By using public participation and smartphones, noise-based monitoring can create accurate and low-cost noise maps (Yao et al., 2013). The utilization of technology also continues to grow. For example, noise monitoring can be done spatially and temporally by using geographic information system (GIS) technology (Farooqi et al., 2017; Gheibi et al., 2022). In addition, research also continues to be conducted on the impact of noise on health (Adriyani, 2017; Ella Anastasya Sinambela & Mardikaningsih, 2022; Rahman et al., 2022b; Wardani et al., 2020) and education (Zahrany et al., 2022). Despite significant progress, there are still some gaps that hinder comprehensive noise monitoring and management. One of them is that standardized methodologies and comprehensive long-term data to capture variations across different periods and zones within the study area are rarely available. Therefore, this study offers a novelty, namely the application of standardized data collection methods (BSN, 2017) and more comprehensive data variations within 24 hours for each observation point.

This research was carried out with the purpose of identifying the noise levels that occur and analyzing the distribution of noise generated by the Telaga Diesel Power Plant based on geospatial. Geospatial analysis allows for a more comprehensive visualization of the distribution of noise levels in different areas, and helps in identifying the most affected areas. GIS allows the collection, storage, manipulation and analysis of spatial data, thus providing a more comprehensive understanding of noise distribution and intensity (Mihalache et al., 2023). As a result of this research, it is expected in the foreseeable future, there will be a balanced solution between the operation of the PLTD Telaga and the welfare of the people living around it. Thus, the results of this analysis can be used as a reference in noise mitigation efforts and spatial planning in residential areas around PLTD Telaga.

METHODS

Research Location

This research was conducted in the residential area around Telaga Diesel Power Plant (PLTD) PT PLN (Persero) SULUTTENGGO Region, Gorontalo Branch. Administratively located in Paguyaman Sub-district, Kota Tengah District, Gorontalo City, Gorontalo Province. Astronomy located at 122^0 59' 44" to 123^0 05' 59" East and 0^0 28' 17" to 0^0 35' 56" North, and geographically bordered by :

1) North bordered by Prof. Dr. Jhon Ario Katili Street and Tapa village
2) South bordered by Jalan Bali and residential areas of Pulubala Village.
3) The east is bordered by residential areas of Paguyaman Village.
4) The west is bordered by Jalan K.H Agus Salim and residential areas of Tomulobutao Village (Figure 1).

The Telaga Diesel Power Plant area is located in residential area. Because of its existence in urban areas, the area around PLTD Telaga is inhabited by people with various cultural backgrounds and diverse occupations. Around this area, there are community settlements along with various other public facilities such as schools, houses of worship, and health facilities. In addition, in this area there are several small industries and shopping places such as clothing stores, kiosks and minimarkets. Therefore, the PLTD Telaga is surrounded with bustling community activities both during the day and night.

Research Variables

In this study, the research variable is the noise level, which is the intensity of noise measured in a certain area due to the presence of noise sources, both the PLTD Telaga power plant engine and other sources that cause noise such as public vehicles, welding machine activities, car repair shops, and other sources that cause noise.

Data Type and Source

The data used in this study consist of primary data and secondary data. Primary data are research data obtained directly from data sources that are collected and directly related to the results studied. The primary data used in this research were in the form of observation point coordinate data and noise level values at each observation point. Meanwhile, the secondary data were data obtained from related agencies that can support more accurate research results. Secondary data used were obtained from the Gorontalo City Central Bureau of Statistics, Paguyaman Sub-district Office, RTRW Map of Gorontalo City, and PLTD Telaga Office.

Data Collection Methods

Data collection in this study was carried out using a simple noise measurement method by directly measuring the noise level using a sound level meter (Kallankandy & Deswal, 2023). The measurements were carried out at 43 different location points and scattered in the Telaga PLTD work area and residential areas around the PLTD Telaga (Figure 2).This noise study was conducted when the engine was active for approximately 10 minutes at each measurement point (BSN, 2017).

Noise level measurements were carried out in 2 groups of PLTD Telaga operational time, namely Normal Load time and Peak Load time. Normal Load conditions at 06.00 am - 22.00 pm and Peak Load use of electric current starts from 22.01 pm - 06.00 am. Noise measurements were carried out during 24-hour activities by looking at the highest activity for 10 hours at the interval of 06.00 - 22.00 WIB, and activity at night for 8 hours at the interval of 22.00 - 06.00 WIB (BSN, 2017). Measurements were carried out as many as 7 measurement times representing specific time intervals, 4 measurement times during the day and 3 measurement times at night. The list of measurement time representation can be seen in Table 1.

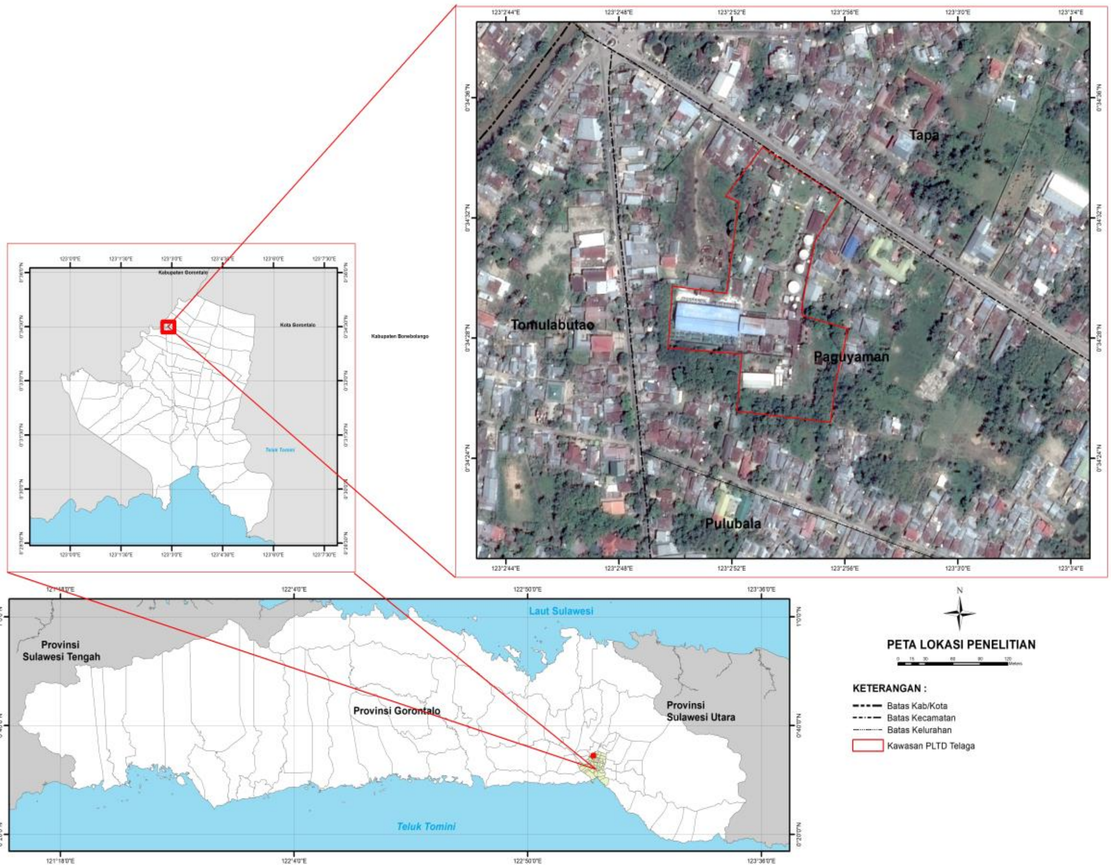

Figure 1. Map of Research Location in the Paguyaman Sub-district, Kota Tengah District, Gorontalo City, Gorontalo Province

Table 1. Measurement Time of Noise Level

No.	Measurement Time	Time Represented	Description
1	07.00 AM	06.00 - 09.00 AM	Normal Load
2	10.00 AM	09.00 - 12.00 AM	Normal Load
3	15.00 PM	12.00 - 17.00 PM	Normal Load
4	20.00 PM	17.00 - 22.00 PM	Normal Load
5	23.00 PM	22.00 - 24.00 PM	Peak Load
6	01.00 AM	24.00 - 03.00 AM	Peak Load
7	04.00 AM	03.00 - 06.00 AM	Peak Load

Data Analysis

The data analysis used in this study used noise level analysis and spatial analysis.

1) Time Noise Level (Leq - Equivalent Continuous Noise Level)

The division of Normal Load and Peak Load times causes the operation of PLTD machines to be unstable. Therefore, in calculating the noise level, Leq - Equivalent Continuous Noise Level was used, which is the average noise during a certain period of time (Garjito & Suprayogi, 2012; Zhang & Pei, 2016). Leq is calculated by the formula 1.

$$Leq = 10 \times \log_{10}\left(\frac{1}{T}\int_0^T 10^{\frac{L(t)}{10}}\,dt\right) \tag{1}$$

with:
Leq = Equivalent noise level (in dB)
L(t) = Noise level at a specific time (in dB)
T = Duration of measurement time

2) Spatial analysis

The spatial analysis approach was used to see the distribution of noise levels in the PLTD generator area and the residential areas around PLTD Telaga. Existing noise level data is further analyzed based on GIS (Chen & Wang, 2020; Gheibi et al., 2022). It is carried out by entering the measurement coordinates as a location reference and noise level data as attribute data, then analyzing the data with the interpolation method (Mihalache et al., 2023). The research framework can be seen in Figure 3.

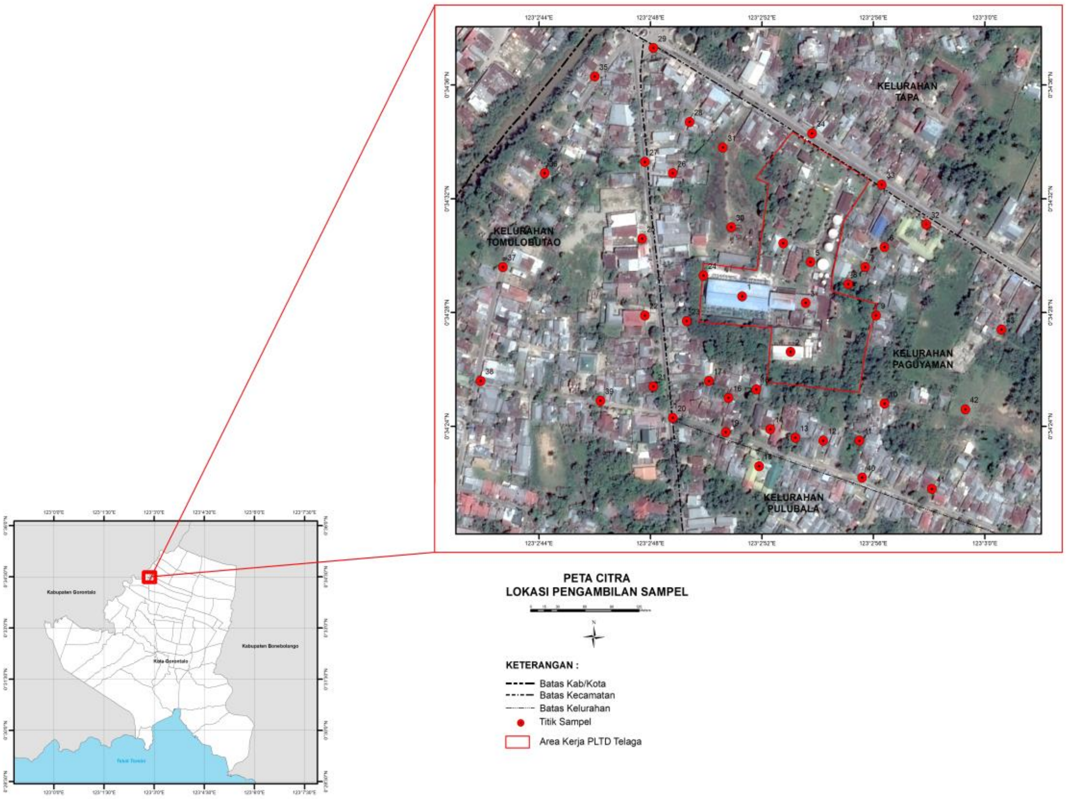

Figure 2. Map of Sampling Location

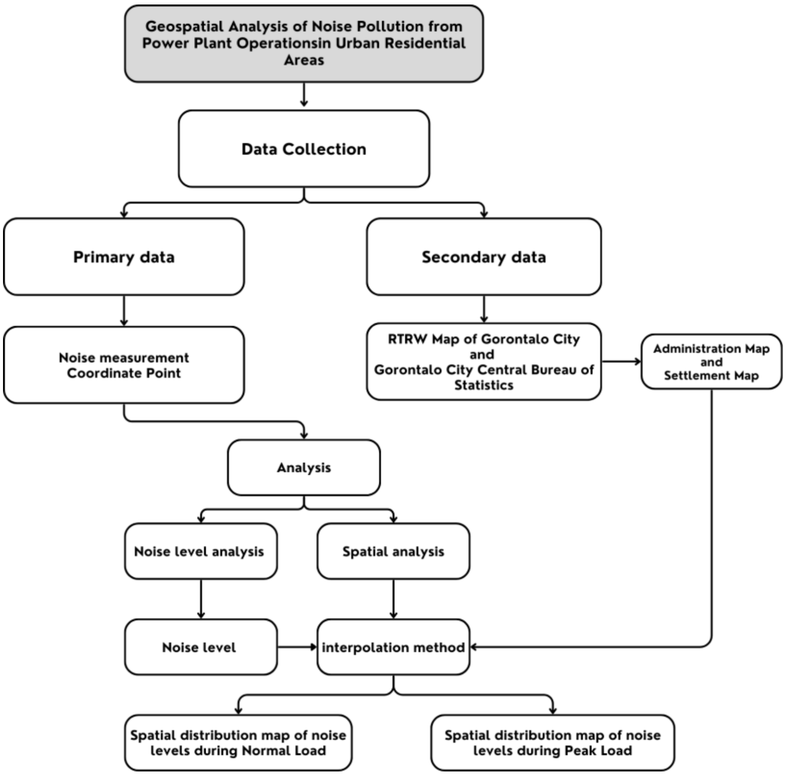

Figure 3. Framework research

RESULTS AND DISCUSSION

Noise Level

The results of the calculation of noise levels in the Telaga Diesel Power Plant (PLTD) area were divided into noise levels during Normal Load times and noise levels during Peak Load times.

1. Normal Load

Noise levels in the PLTD Telaga work area were quite varied (Table 2). Based on the results of noise measurements at five different points in the PLTD Telaga work area, it was found that the noise level around the engine area reached an average of 102 to 109 dBA, which far exceeded the occupational noise quality standard limit regulated by Ministry of Manpower Decree No. 51/MEN/1999, which is 85 dBA for an exposure time of 8hours per day (Menteri Tenaga Kerja Republik Indonesia, 1999). At another measurement point, located at an employee's house, the noise level decreased significantly to 73 dBA, but still exceeded the environmental noise limit for residential areas, set at 55 dBA by Ministry of Environment Decree Kep. 48/MENLH/11/1996 (Menteri Negara Lingkungan Hidup, 1996).

Based on the results of noise measurements in residential areas around PLTD Telaga (Table 3), there were significant variations in noise levels at various points. The measurements showed that the noise level in residential areas varied between 53 dBA to 77 dBA, which exceeds the threshold set by Ministry of Environment Decree Kep. 48/MENLH/11/1996, which is 55 dBA for residential areas. The highest noise level in the residential area was recorded at Point 29, with noise levels reaching 77 dBA. This is an indication that the area was heavily affectedby the noise from the PLTD Telaga operation. On the other hand, there were points with relatively lower noise, such as at Point 42 and Point 43, which recorded noise of 53 dBA and 51 dBA respectively. These noise levels were below or close to the limits permitted by Ministry of Environment Decree Kep. 48/MENLH/11/1996.

Table 2: Noise Levels of the PLTD Telaga Work Area - Normal Load Time

No.	Code	Average noise (dBA)	Quality Standard and Unit	Description
1	Point 1	102	85 dBA*	Machine area
2	Point 2	109	85 dBA*	Machine area
3	Point 3	107	85 dBA*	Machine area
4	Point 4	73	55 dBA **	Employee's house
5	Point 5	85	85 dBA*	Machine area

Description:
(*) : Ministry of Manpower Decree No. 51/MEN/1999 concerning Threshold Limit Value (NAB) for Physical Factors in the workplace with an exposure time of 8 hours/day.
(**) : Ministry of Environment Decree Kep. 48/MENLH/11/1996 regarding noise level quality standards for residental area.

Table 3. Noise Level in Residential Area of PLTD Telaga - Normal Load Time

No.	Code	Average noise (dBA)	Quality Standard and Unit *	Description
1	Point 6	70.86	55 dBA	Residential
2	Point 7	75.89	55 dBA	Residential
3	Point 8	83.68	55 dBA	Residential
4	Point 9	76.75	55 dBA	Residential
5	Point 10	72.86	55 dBA	Residential
6	Point 11	65.69	55 dBA	Residential
7	Point 12	63	55 dBA	Residential
8	Point 13	61	55 dBA	Residential
9	Point 14	62	55 dBA	Residential
10	Point 15	75.67	55 dBA	Residential
11	Point 16	71	55 dBA	Residential
12	Point 17	73.75	55 dBA	Residential
13	Point 18	60	55 dBA	Residential
14	Point 19	60	55 dBA	Residential
15	Point 20	69.5	55 dBA	Residential
16	Point 21	66	55 dBA	Residential
17	Point 22	70.8	55 dBA	Residential
18	Point 23	67	55 dBA	Residential
19	Point 24	67.55	55 dBA	Residential
20	Point 25	68.66	55 dBA	Residential
21	Point 26	62.5	55 dBA	Residential
22	Point 27	71.87	55 dBA	Residential
23	Point 28	57.7	55 dBA	Residential
24	Point 29	77	55 dBA	Residential
25	Point 30	76	55 dBA	Residential
26	Point 31	64	55 dBA	Residential
27	Point 32	62.67	55 dBA	Residential
28	Point 33	69.9	55 dBA	Residential
29	Point 34	76.89	55 dBA	Residential
30	Point 35	65.6	55 dBA	Residential
31	Point 36	60	55 dBA	Residential
32	Point 37	63	55 dBA	Residential
33	Point 38	65	55 dBA	Residential
34	Point 39	61	55 dBA	Residential
35	Point 40	59	55 dBA	Residential

No.	Code	Average noise (dBA)	Quality Standard and Unit *	Description
36	Point 41	56.65	55 dBA	Residential
37	Point 42	53	55 dBA	Residential
38	Point 43	51.6	55 dBA	Residential

Description:
(*) : Ministry of Environment Decree Kep. 48/MENLH/11/1996 on noise level quality standards for residential areas.

2. Peak Load

Based on the results in Table 4, the noise level in the PLTD Telaga work area during Peak Load has a significant difference with Normal Load time. The results of measurements at five points, the highest noise was at Point 2 and Point 3, which were 110 dBA and 109 dBA respectively, which occurred in the engine area. This noise level is higher compared to the same location during operational measurements of the PLTD engine during Normal Load (Table 2). These noise levels were far above the permissible threshold for work areas, which is 85 dBA as stipulated by Ministerial Decree No. 51/MEN/1999 on Threshold Limit Value (NAB) in the workplace with an exposure time of 8 hours per day. At Point 4, which was located at an employee's house, the measured noise reached 78 dBA, which is still above the noise quality standard for residential environments, which is 55 dBA based on Ministry of Environment Decree Kep. 48/MENLH/11/1996. Although the noise in the residential area was lower than in the machinery area, it was still at a level that can affect the comfort and health of residents. At Peak Load times, the noise level at Point 1 reached 82 dBA. At this point, the noise level did not exceed the prescribed threshold. Point 5 reached 87 dBA, although relatively low when compared to what happened at Point 2 and Point 3, this noise level still exceeded the allowable threshold (Table 4). The contrast of the noise levels that occured in the PLTD Telaga work area during Normal Load and Peak Load was clearly visible (Figure 4), however, the overall analysis results showed a trend in decreasing noise levels outside the PLTD Telaga work area (Figure 5).

Table 4. Noise Level of PLTD Telaga Work Area - Peak Load Time

No.	Code	Average noise (dBA)	Quality Standard and Unit	Description
1	Point 1	82	85 dBA*	Machine area
2	Point 2	110	85 dBA*	Machine area
3	Point 3	109	85 dBA*	Machine area
4	Point 4	78	55 dBA**	Employee's house
5	Point 5	87	85 dBA*	Machine area

Description:
(*) : Ministry of Manpower Decree No. 51/MEN/1999 concerning Threshold Limit Value (NAB) for Physical Factors in the workplace with an exposure time of 8 hours/day.
(**) : Ministry of Environment Decree Kep. 48/MENLH/11/1996 regarding noise level quality standards for residental area.

Spatial Distribution of Noise

The spatial distribution of noise at Normal Load time shows that the noise distribution that occured in the PLTD telaga work area was on average >75 dBA (Figure 6). The highest accumulation of noise levels was around the power plant engine area with noise levels above 85 dBA. Overall, the noise level that occured in the engine area lasted for 12 hours with noise levels above 85 dBA. In addition to the PLTD Telaga work area, it was evident that the high noise distribution reached the residential area. The noise level recorded around the residential area was 65 dBA - 85 dBA (Table 5). However, the area exposed to noise in the range of 75 dBA - 85 dBA was not spacious enough locating on the east side of the PLTD Telaga area. While area with noise level in the range of 65 dBA - 75 dBA was quite spacious in the residential area to the west and north of the PLTD Telaga area. In addition, it can also be seen that a small part of the residential area on the Prof. Dr. Jhon Ario Katili section was in the noise exposure range of 75 dBA - 85 dBA (Figure 4).

Table 5. Noise Level in Residential Area of PLTD Telaga - Peak Load Time

No.	Code	Average noise (dBA)	Quality Standard and Unit *	Description
1	Point 6	74	55 dBA	Residential
2	Point 7	78.7	55 dBA	Residential
3	Point 8	83.98	55 dBA	Residential
4	Point 9	77	55 dBA	Residential
5	Point 10	73.85	55 dBA	Residential
6	Point 11	64	55 dBA	Residential
7	Point 12	56.9	55 dBA	Residential
8	Point 13	60.9	55 dBA	Residential
9	Point 14	64.67	55 dBA	Residential
10	Point 15	76	55 dBA	Residential
11	Point 16	70	55 dBA	Residential
12	Point 17	74	55 dBA	Residential
13	Point 18	61	55 dBA	Residential
14	Point 19	64.8	55 dBA	Residential
15	Point 20	69	55 dBA	Residential
16	Point 21	64	55 dBA	Residential
17	Point 22	67.67	55 dBA	Residential
18	Point 23	65.9	55 dBA	Residential
19	Point 24	56	55 dBA	Residential
20	Point 25	54	55 dBA	Residential
21	Point 26	51	55 dBA	Residential
22	Point 27	55	55 dBA	Residential
23	Point 28	50.56	55 dBA	Residential
24	Point 29	64	55 dBA	Residential
25	Point 30	76	55 dBA	Residential
26	Point 31	62	55 dBA	Residential
27	Point 32	53	55 dBA	Residential
28	Point 33	52.7	55 dBA	Residential
29	Point 34	61.6	55 dBA	Residential
30	Point 35	65	55 dBA	Residential
31	Point 36	53	55 dBA	Residential
32	Point 37	50.57	55 dBA	Residential
33	Point 38	50	55 dBA	Residential
34	Point 39	52	55 dBA	Residential
35	Point 40	50	55 dBA	Residential
36	Point 41	52	55 dBA	Residential
37	Point 42	52	55 dBA	Residential
38	Point 43	50.8	55 dBA	Residential

Description:
(*) : Ministry of Environment Decree Kep. 48/MENLH/11/1996 on noise level quality standards for residential areas.

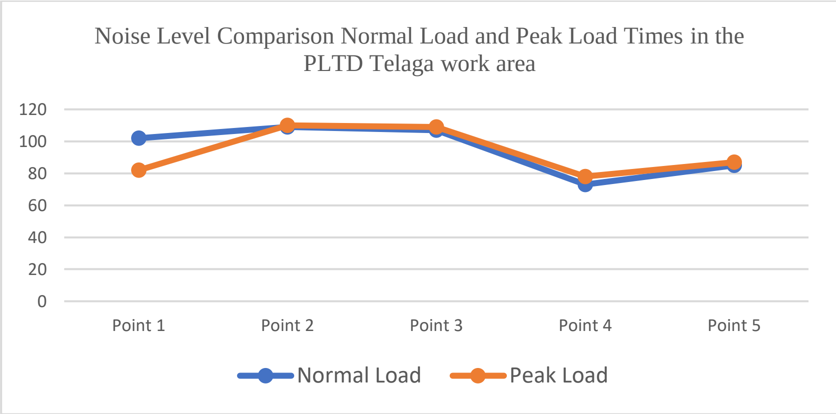

Figure 4. Comparison chart of noise levels in the PLTD Telaga work area

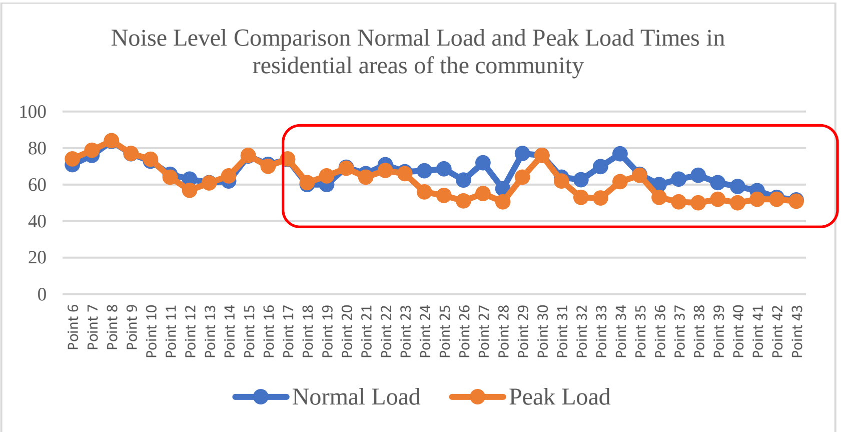

Figure 5. Comparison chart of noise levels in residential areas of the community

The noise level at the Peak Load time of PLTD operations showed that the highest spatial distribution of noise levels was in the PLTD Telaga work area (Figure 7). The condition was the same as during Normal Load time where the noise exposure time in this area lasted for 12 hours. Therefore, the same risk will also be experienced by workers who do shifts during Peak Load operating hours. For this reason, workers still need to use PPE (Meilasari et al., 2021; Wardani et al., 2020). Apart from workers, in the location of the PLTD Telaga area there were also housing for employees. Thus, the potential impact will be much higher. The limit for noise exposure in areas that are used as settlements or housing is a maximum of 55 dBA, as per Decree Kep. 48/MENLH/11/1996 regarding noise level quality standards for residential areas (Menteri Negara Lingkungan Hidup, 1996).

A significant difference can be seen in the distribution of noise in residential areas outside the working area of PLTD Telaga. Although the highest noise was recorded during the Peak Load time (Figure 6), which amounted to 109-110 dBA, the noise level that reached the residential area was much lower and smaller in distribution when compared to the spatial distribution during Normal Load. The residential area located north of the PLTD received noise exposure less than 65 dBA. Exposure to noise in the western residential area was quite varied, such as: a small portion of the settlement on the edge of Road KH. Agusalim and the intersection of the Bali street were affected by noise exposure in the range of 65 DBA - 75 dBA; a small portion was in the range of 55 dBA - 65 dBA; and the rest was lower than 55 dba. The southern residential area was also affected by noise that was not much different from the western residential area of PLTD Telaga. The eastern residential area was also affected by noise coming from PLTD Telaga.

By looking at the Minister of Labor Decree No. 51/MEN/1999 concerning Threshold Limit Values (NAB) for Physical Factors in the workplace with an exposure time of 8 hours/day (Ministry of Manpower of the Republic of Indonesia, 1999), workers or employees who carry out activities around the area are very vulnerable to health problems. These health problems can be related to hearing loss (Ella Anastasya Sinambela & Mardikaningsih, 2022), blood pressure and pulse disorders (Adriyani, 2017; Hartanto, 2011), psychological disorders related to emotions (Darlani dan Sugiharto, 2017; Meilasari et al., 2021). To avoid the impact of high noise, mitigation efforts need to be made by examining workers' health, organizing work shifts, installing safety sign, conducting maintenance on machines (Meilasari et al., 2021) and using ear protective equipment such as earplug and earmuff (Meilasari et al., 2021; Wardani et al., 2020).

In addition to seeing the distribution of noise distribution, this map also provides additional information related to other sources of noise that occur in residential areas. The noise level distribution map of Normal Load time (Figure 6) showed the noise distribution in almost the entire research area went beyond the limit of the quality standards that have been set for residential areas and the working area of the PLTD Telaga engine. Meanwhile, the spatial distribution of noise at Peak Load times appeared to have decreased significantly. Data results showed that the noise level generated by the PLTD engine was higher during Peak Load, the affected area should be larger than during Normal Load times (Keith Attenborough & Horoshenkov, 2007). This shows that the noise that occurs in residential areas during Normal Load is not entirely from the operation of the PLTD Telaga engine.

The occurrence of noise spikes in some of the northern residential areas during Normal Load and during Peak Load this area had a lower impact, this means that there were other sources that contributed to the noise impact. Because PLTD Telaga is located in the Jhon Ario Katili road area, which is a national road, it can be concluded that other noise pollution in this area were the results of motor vehicle activities. The western residential area also experienced a significant decrease in noise impact. Initially, during Normal Load the recorded noise impact in the residential area reached 75 dBA - 85 dBA but during Peak Load the highest recorded noise impact only reached the range of 65 dBA - 85 dBA. That noise was found at the intersection of KH. Agusalim road and Bali road. In addition, at that location there was a motorized rickshaw (bentor) assembly workshop which is a local vehicle of the Gorontalo community. The eastern settlement and the southern settlement relatively had the same noise distribution, both during normal and Peak Load engine operation times. This indicates that the noise in this area came from the operational activities of the PLTD Telaga engine. Therefore, mitigation efforts or actions are needed to be taken by the PLTD Telaga to reduce the impact of engine activity noise so that the noise pollution do not to reach residential areas. Efforts that can be made by the PLTD in reducing the noise that reaches the community is by installing a silencer. Mechanical dampers on the part of the generating machine building will be quite effective in reducing noise levels. In addition, planting various types of trees in the area around the generating machine will be able to reduce noise levels (Anam et al., 2019; Hamidun et al., 2021; Natalia, 2022; Putra et al., 2019).

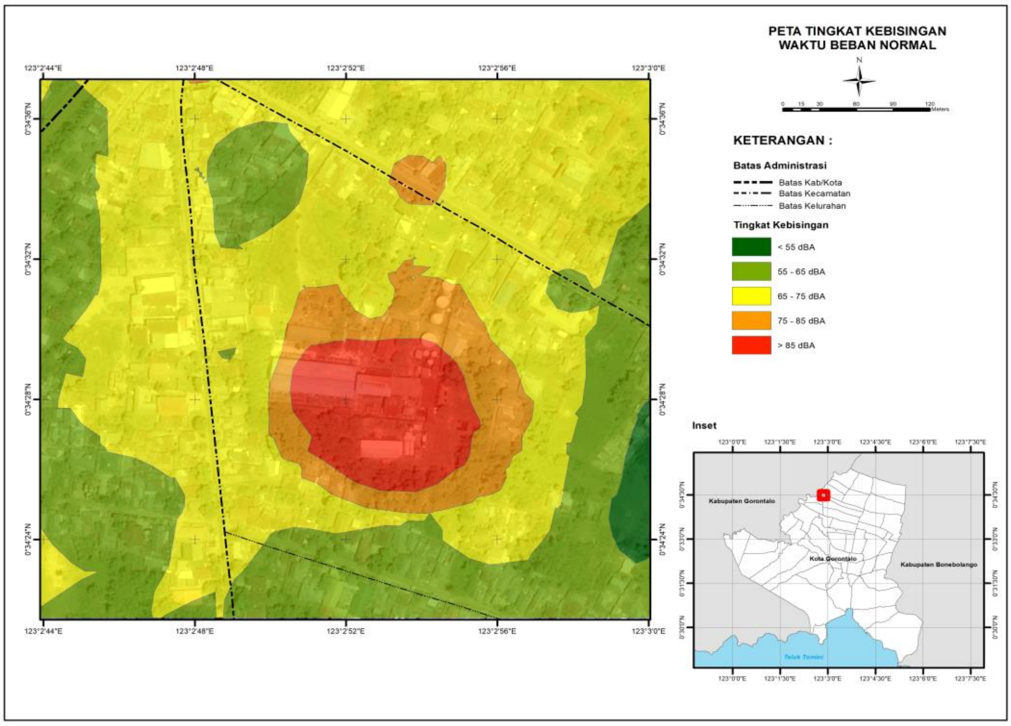

Figure 6. Spatial distribution map of noise levels during Normal Load

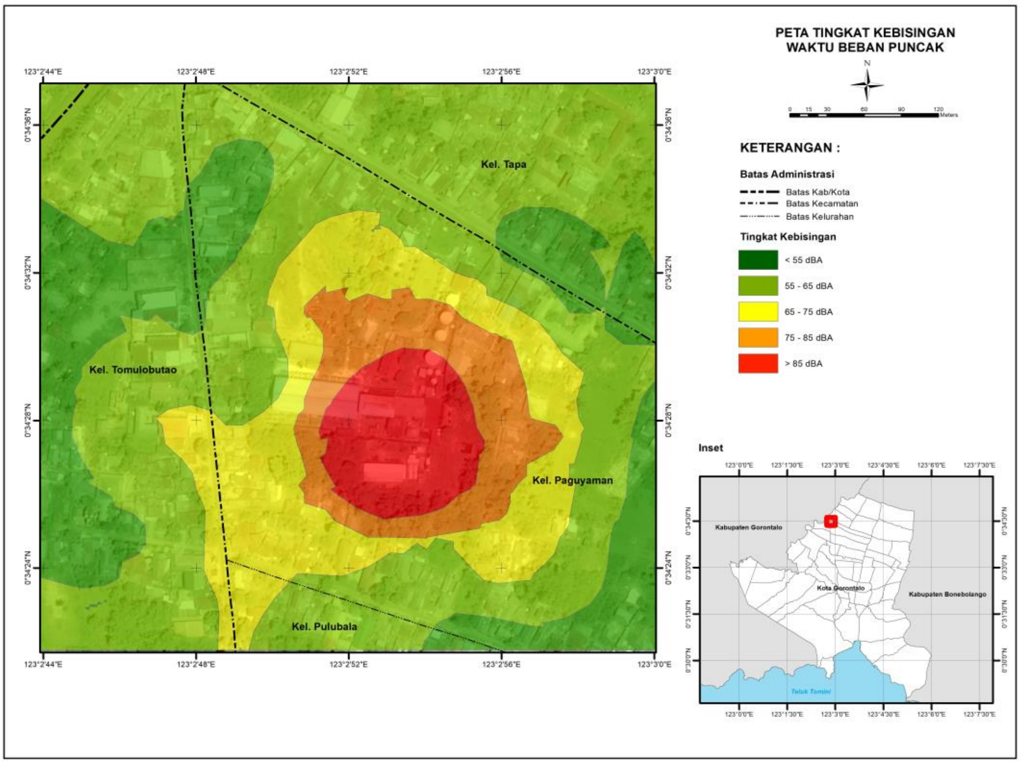

Figure 7. Spatial distribution map of noise levels during Peak Load

CONCLUSION

The conclusion from the results of this study is that the noise level that occurs in the PLTD Telaga area during engine operation at Normal Load time and Peak Load time has exceeded the quality standard for workers. The highest noise during Normal Load time was at Point 2 located at the PLTD Telaga engine area with noise levels reaching 109 dBA. The lowest noise during Normal Load time was at Point 43 located at the residential area with a noise level of 51.6 dBA. The highest noise level during Peak Load time is at Point 2 located at the PLTD Telaga engine area with a noise level 110 dBA. The lowest noise at Peak Load time were at Points 38 and 40 located at the residential areas with a noise level of 50 dBA. The distribution of noise levels in the work area and residential areas was quite varied. The highest noise distribution in residential areas was in the north and west residential areas and occured during Normal Load time machine operations. The eastern residential area and the southern residential area have relatively the same noise distribution, both during normal and Peak Load engine operation. The source of noise in the northern and western settlements during Normal Load time operations did not only come from the PLTD Telaga engine, but also came from other sources such as motor vehicle activities and motorized rickshaw assembly workshops.

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