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Regional Case Study

Noise Level of Railroad Settlements JPL 05 Kaligawe Street, Semarang

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Abstract
Noise is unwanted sound at a particular time and is sourced from any source. Data from the Pusarpedal Laboratory and the Ministry of Environment and Forestry of the Republic of Indonesia show that railroad settlements' noise in Yogyakarta, Surabaya, Semarang, and Bandung is beyond quality standards. Tambakrejo Village, Gayamsari District, Semarang, one of the railroad settlements at JPL 05 Kaligawe Street, Semarang area, close to a railroad. This research aims to know the noise level of the settlements. The sampling of noise level is done for 24 hours by measuring the noise for each time interval, with a total of 16 measuring points for 4 areas with various distances, 2.5 m, 5 m, 10 m, and 15 m. The sampling result shows that the railroad settlements have a noise level rate of 91.8 dB at a distance of 2.5 m, 89.5 dB at 5 m, 85.2 dB at 10 m, and 81.5 dB at 15 m. According to NOISE REL regulation, the maximum noise level allowed is 85.57 dB during 421 minutes or 7.02-hour of exposure. This sampling result shows that the noise levels are beyond of quality standards of both NIOSH REL and PermenLH No. 48/1996.

Keywords: *Noise* exposure; noise level; noise modelling; surfer software

1. Introduction

Noise is a sound or sound at a certain time that is not desired by humans. According to Marisdayana et.al (2016), noise is unwanted sound, originating from natural activities and human activities. Noise comes from various sources, including transportation activities. Trains are the preferred means of transportation. Girang (2021) mentions the locomotive engine, the friction of the wheels with the rails, the sound of railroad crossing signals, and the combustion process producing train noise.

PermenLH No. 48 of 1996 concerning Raw Noise Levels states that noise level is a measure of sound in units of decibels (dB). Rizky (2017) stated that the noise level is divided into two, namely the equivalent continuous noise level and the recommended and permissible noise level. *Equivalent Continuous Noise Level (Leq),* the continuous noise level is the same as intermittent noise in a given time interval. Recommended and permissible noise levels, day, evening, and night noise levels are taken based on the average noise level mode value. Noise level is an important aspect of noise parameters. Haryono and Sri (2008) mentioned that there are 3 important aspects of noise parameters, namely noise level (SPL), length of noise (percentage of noise events in a certain period) which is hereinafter referred to as noise intensity, and the pattern of water (day and night noise cycles). In addition, it is stated that there are two noise terminologies, namely ambient noise, and *background* noise.

Haryono and Sri (2008) state some of the effects of noise that can occur *Temporarily Threshold Shifts* (TTS) or temporary hearing loss, and *Permanent Threshold Shifts* (PTS). *The auditory effect*, is a disturbance in the ear organs in controlling noise, especially the muscles of the middle ear. Acoustic trauma, that is, permanent hearing loss due to very short and very loud exposure to noise. Conversation disorder or *marking effect*, which is a complex function of the speaker's distance from hearing and the frequency of spoken words is disturbed. Sleep disturbances, namely disturbances in the sleep stage (drowsiness, breaks, sleep) due to the presence of waking up due to noise, suppleness, length of noise, and age factors. Psychological disorders, namely human psychic disorders in the form of irritability, irritability, and offense are ignited due to excessive noise. Noise above 70 dB can cause anxiety, lack of well-being, hearing saturation, stomach pain, and circulatory problems. If it exceeds 85 dB, it can cause hearing loss, even heart disease, and high blood pressure if it lasts for a long time (Mayangsari, 2010).

Train noise is produced by friction between wheels, the signal sounds at train crossings, and the combustion process on trains Girang (2021). Girang (2021) mentions that train noise depends on the speed of the train, the type of engine, the number of carriages, wheels, and the number of trains. There is not so much difference between the noise of electric trains and diesel trains. Previous design study stated that the noise value of electric trains and diesel trains is not much different, namely stated by Wati (2020), the noise value of electric trains is 73.8 dBA at a distance of 40 m and by Yumni (2019) the noise value of diesel trains is 76.6 dBA at a distance of 48 m.

According to the Law of the Republic of Indonesia No. 23 of 2007 concerning Railways, a train is a transportation that operates by railway facilities, moving or walking alone or is assembled on railroad tracks. Trains are the preferred means of transportation by the community for long distances and short periods. Train noise is noise exceeding the standard derived from the operation of the train at a certain level and time, which can endanger the health and comfort of living things and the environment. Settlements are dwellings consisting of more than one housing equipped with infrastructure, facilities, and public utilities, supporting other activities in urban and rural areas (Law No.1 of 2011).

The settlement of Tambakrejo Village, Gayamsari District, Semarang City is a settlement located near the JPL 05 railroad tracks, Jl. Kaligawe Semarang. Based on field observations that have been made, these settlements are close to the railroad tracks, especially in settlements located along KM 2+400 to 2+800 Lintas Semarang Gambringan JPL 05 Jl. Kaligawe, Semarang. In these settlements, several houses are ± 2 - 5 m from the train tracks. Based on these problems, the authors conducted a study to determine the noise level in the railroad settlements JPL 05 Jl. Kaligawe Semarang, whether it still meets or has exceeded the applicable noise quality standards.

Previous research stated that noise in railway settlements exceeds quality standards. The Pusarpedal Laboratory with the Ministry of Environment of the Republic of Indonesia (2012) stated through the Noise and Vibration Research that Yogyakarta, Surabaya, Semarang, and Bandung have railroad settlement noise levels beyond the quality standard. Several previous studies prove the existence of noise levels beyond the quality standards in railway settlements. Eka Arista and Rianto Rili, 2017 in their design entitled "Design of Barrier Making to Reduce Train Noise Due to *Double Track* of Railway Lines in the Cross-Manggarai Residential Area – Bekasi" mentioned the value of the increase in the noise obtained at 5 points of variation of distances (10 m, 20 m, 30 m, 40 m and 50 m) were 102.7 dBA, 101.3 dBA, 99.8 dBA, 98.3 dBA, and 91.8 dBA, respectively. Ajeng Putri Mayangsari, 2010 in her design entitled "Designing Barriers to Reduce Noise Levels on Railway Lines on Jalan Ambengan Surabaya Using the Nomograph Method" stated that the noise level along the railway line was obtained beyond the NAB limit with a maximum value of 92.76 dBA. The distance between the railway and the location of the residential area is limited to only 8.5 m. Dinda Nur Aulia Septiani and Candra Nugraha, 2021 "Noise Control Planning. Case Study: Paper Company *Rewinder Machine* Area", known Noise at 11 measuring points exceeds the threshold value (NAV) of 86.6 dBA, 87.8 dB, 89.4 dBA, 91.7 dBA; 89.8 dBA, 88.7 dBA, 85.5 dBA, 89.4 dBA, 88.3 dBA, 88.1 dBA, 83.3 dBA, and 85.4 dBA so necessary, so noise reduction is needed.

But, most of the previous study and research does not show a mapping of the distribution of noise at the site, so the information from the study is still slightly lacking. So, this study research was conducted to find out the noise level in one of Semarang's area railroad settlements located at Tambakrejo Village, Gayamsari District, Semarang City with differences in distances and do noise modeling for the noise level visual. This research is expected to be useful for the railroad settlement community JLP 05 Jl. Kaligawe Semarang is a reference for efforts to pay attention and be aware of the quality of their dwelling. This study research by the sampling can be used to make some designs to reduce the noise level to create settlements with good environmental quality, especially on the problem of noise from trains. This design is expected to be input and material for consideration in efforts to control noise in railroad settlements and efforts to create more orderly and proper settlements. This design focuses on designing *barriers* or barrier walls to control noise in the JPL 05 Jl. Kaligawe Semarang railway settlement properly, effectively, and efficiently from various aspects. To create a decent settlement around the railroad tracks, namely with a safe noise level by applicable regulations from both the central and local governments.

2. Material and Methods

Data collection in this design includes primary data collection and secondary data collection. Primary data and secondary data were obtained from the results of field observations, documentation, interviews, and requests for accurate data from related parties such as the government and agencies/companies related to this design. Data processing is carried out in different ways depending on the type of data and the desired data processing results. Data processing is related to the use of software, input, and output of primary and secondary data. Data analysis in this design is carried out descriptively, by describing the results of data collection, data collection, and data processing in the form of tables, narratives, graphs, images, and others.

Field data as the main data in the form of existing conditions of the research location, coordinates of sampling points, and noise levels of sampling results at the research site. Meanwhile, literature data as supporting data in the form of noise level quality standards, research location maps, train schedules, and use of railroad tracks. The research process uses several software, tools, and materials including, ArcGIS, Surfer, SLM, GPS, Noise datasheet, and stationery.

Sound Level Meter (SLM) is used to measure the noise level at the measurement point during the sampling implementation. Celestina et.al (2018) mentioned that *the Sound Level Meter* is a tool for measuring noise levels, consisting of microphones, amplifiers, "*affenuator" circuits,* and several other devices. SLM is capable of measuring noise at levels 30-130 dB and frequencies of 20-20,000 Hz. The working principle of SLM is the SLM's response to vibrations in changes in air pressure due to ambient activity. SLM consists of a microphone and a reading display. Microphones are used for the identification of shifts in air pressure, which are then converted into electrical signals. Then, it is processed on the display reading and displayed in units decibel (Girang, 2021).

The Global Positioning System (GPS) is used to capture the coordinate points of the measuring points selected for noise level measurements in this design. *Global Positioning System* or GPS is a satellite-based navigation system consisting of 24 satellite networks placed in orbit. (Rizky, 2017). The way GPS works are through a GPS *receiver* that retrieves user location information through *triangulation calculations.* The time of signal sent with the time of the received signals is compared so that satellite distance is obtained. Through distance calculation, the position of a user is then displayed in maps by the GPS *receiver*. The signal captured by the GPS *receiver* can be in the form of two satellite signals with 2D coordinate results (latitude and longitude) or the form of four or more satellite signals with 3D coordinate results (latitude, longitude, and *altitude) (*Rizky, 2017).

The noise datasheet is used to record the noise level value of the sampling process on the LTM5 measurement, which is the taking of noise data for ± minutes every 5 seconds. A noise datasheet will be created for each point of each of the 7 measurement time ranges. A noise datasheet is created for each measurement in 3 columns, with the first 12 column data being for the noise level of the sampling results before the train passes for 1 minute, the second column for the level of probability of sampling results as the train passes for ± 15 – 30 seconds, and 12 data in the third column for the noise level after the train passes for 1 minute. The stationery used is a ballpoint or pencil to record the results of noise level measurements on the noise datasheet.

Microsoft Excel or MS. Excel is used to process primary data and secondary data, and data analysis uses certain calculation formula equations that are inputted in an excel formula format.
ArcGIS software is used to make a map of the design location and a map of the noise level mapping output from the surfer software, with the input of primary data coordinates, surfer mapping results, and secondary data in the form of shapefile (SHP) design location maps.

Surfer is software used to create contours. In this design surfer software is used to create a noise contour map that describes the noise level mapping at the design location with the input of the noise level and the coordinates of the measuring points. S*urfer software* is a contour modeling program. The contours in this software require data input and grid input. Input data is data that will be processed to be contoured in the form of a Z - axis, and grid input is the coordinates of points that will be contoured in the form of an X - axis and a Y- axis. Point coordinates in the form of an X axis and a Y axis are the coordinates of a measurement point or sampling point of noise level while the Z axis is the value of the noise level. This software also serves to display coordinate data from the input grid in a 3D form which can be edited to display according to the user's wishes to facilitate the data modeling process (Rizky, 2017).

Noise level sampling is carried out by the Ministry of Environment and Forestry of the Republic of Indonesia No. 48 of 1996 in a direct way, namely using a Sound Level Meter (SLM) measuring device with readings every 5 seconds. Measurements were carried out 24 hours with sampling taken 7 times according to the measurement time range as follows:

- L1 with a time range of 06.00 – 09.00, the measuring time is taken at 7 a.m.
- L2 with a time range of 09.00 – 14.00, the measuring time is taken at 10 a.m.
- L3 with a time range of 14.00 – 17.00, the measuring time is taken at 3 p.m.
- L4 with a time range of 17.00 – 22.00, the measuring time is taken at 8 p.m.
- L5 with a time range of 22.00 – 24.00, the measuring time is taken at 11 p.m.
- L6 with a time range of 24.00 – 03.00, the measuring time is taken at 1 a.m.
- L7 with a time range of 03.00 – 06.00, the measuring time is taken at 4 a.m.

The determination of sampling time is adjusted to field conditions and train schedules from related parties, namely Pusdal OPKA and JPL 05 Officers Kerta Api (KA) Schedule from Pusdal OPKA and train schedule from JPL 05 Jl. Kaligawe Semarang. The survey was carried out in the form of observation of the design location and data collection at the design site, namely the measurement of noise levels at selected measurement points according to guidelines along the settlements to be studied.

Data collection was carried out at the design location in Tambakrejo Village, Gayamsari District, a two-track railway line precisely across Semarang Gambringan kilometers 2 + 400 to 2 + 800 km along 300 m. Along the railway line selected pickup locations are divided into 4 location areas namely A1, A2 representing line 1, B1, and B2 representing line 2. Each area of the site is made with a variety of distances of 2.5 m, 5 m, 10 m, and 15 m from the outer side of the railway tracks. The distance variation is made by considering two conditions, namely less than 6 m, namely at 2.5 m and 5 m, and more than 6 m, namely 10 m and 5 m assuming that the railway boundaries available based on existing conditions are an average width of 6 m. The determination of measurement points or data collection has been adjusted to the provisions for determining the location of noise level measurements for residential areas. Following are the coordinates of the noise level sampling locations presented in Table 1 below:

Table 1. Noise level sampling coordinates

No.	Coordinates		Lokation
	Latitude (LS)	Longitude (BT)	
1	6°57'28.18"S	110°26'47.21"E	A1 (2.5 m)
2	6°57'28.28"S	110°26'47.18"E	A1 (5 m)
3	6°57'28.36"S	110°26'47.04"E	A1 (10 m)
4	6°57'28.48"S	110°26'46.92"E	A1 (15 m)
5	6°57'25.47"S	110°26'44.16"E	A2 (2.5 m)
6	6°57'25.54"S	110°26'44.09"E	A2 (5 m)
7	6°57'25.66"S	110°26'43.98"E	A2 (10 m)
8	6°57'25.78"S	110°26'43.87"E	A2 (15 m)
9	6°57'27.39"S	110°26'47.01"E	B1 (2.5 m)
10	6°57'27.32"S	110°26'47.08"E	B1 (5 m)
11	6°57'27.22"S	110°26'47.21"E	B1 (10 m)
12	6°57'27.13"S	110°26'47.35"E	B1 (15 m)
13	6°57'24.87"S	110°26'44.12"E	B2 (2.5 m)
14	6°57'24.81"S	110°26'44.17"E	B2 (5 m)
15	6°57'24.67"S	110°26'44.25"E	B2 (10 m)
16	6°57'24.52"S	110°26'47.21"E	B2 (15 m)

Noise level measured for almost 3 minutes indeed than 10 minutes cause the noise one to expose just up to 15 seconds – 30 seconds. This measured noise level for 3 minutes includes noise level 1 minute before the train passes; when the train passes, and after the train passes. For the calculation of noise level LTM5, data was used for 1 minute at peak time as peak data for each location, distance, and interval time. Calculation result input at surfer software for contouring the noise exposure at the location. For the guide of procedure, the choice of location and many things related to the noise level were measured based on SNI 8427:2017. The calculations used in this design are the calculation of noise levels, and other calculations with the theory of exponential laws, multiplication, and division to determine the noise level.

Calculation:

Equivalent Noise

LTM5 = 10 log [1/T ni=1 100.01Li ti]

Where:

T = 60 (sampling time is 60 seconds)

Li = Noise level reading result

Ti = 5 (reading interval every 5 seconds)

3. Result and Discussion

The results of measurements and calculations of noise levels at the measuring point of four areas with four variations of distance, namely A1 (2.5 m, 5 m, 10 m, 15 m), A2 (2.5 m, 5 m, 10 m, 15 m). m), B1 (2.5 m, 5 m, 10 m, 15 m) and B2 (2.5 m, 5 m, 10 m, 15 m) exceed the noise quality standard according to PermenLH No. 48 of 1996 as follows.

The data from the measurement of the noise level that has been obtained through on-site sampling is then processed in the calculation of the equivalent noise level at each interval or period. Each sampling data is taken 12 data or the equivalent of noise level data for 1 minute every 5 seconds. Where, the 12 data are the noise level at peak times including the noise level before the train passes, when the train passes, and after the train passes through the noise level meter. LTM5 as Leq for each time range (L1, L2, L3, L4, L5, L6, and L7), with 12 peak data or the equivalent of noise for 1 minute at intervals. Table 2, calculations are carried out for all sampling data as follows:

$$LTM5 = 10 \log [1/T\ \Sigma^{n}_{i=1} 10^{0.01Li}\ ti]$$

$$LTM5 = 10 \log [1/60\ ((10^{0.01x68} \times 5) + (10^{0.069} \times 5) + (10^{0.070} \times 5) + (10^{0.073} \times 5) + (10^{0.071} \times 5) + (10^{0.090} \times 5) + (10^{0.089} \times 5) + (10^{0.086} \times 5) + (10^{0.076} \times 5) + (10^{0.073} \times 5) + (10^{0.074} \times 5) + (10^{0.071} \times 5))]$$

$$LTM5 = 82.5\ dB$$

Table 2. L1 peak noise data (A1 distance 2.5m)

L1 (A1 – 2.5 m) (dB)		
68.1	89.6	75.5
69.3	88.7	72.5
70.2	85.5	73.8
72.9		71.3
70.5		

The noise peak data of each time interval at each point can be seen more fully in the appendix. The results of the LTM5 calculation of all sampling data for each time interval and variations in the distance of each sampling location can be seen in the table below:

Table 3. 2.5 m noise level

Location	L1	L2	L3	L4	L5	L6	L7
A1	82.5	86.3	83.0	88.7	88.9	88.3	87.9
A2	91.5	88.2	89.7	90.8	90.6	91.2	90.9
B1	89.7	78.8	86.8	86.0	87.2	88.6	91.8
B2	91.0	91.2	90.7	91.0	91.5	90.7	91.7

Table 4. 5 m noise level

Location	L1	L2	L3	L4	L5	L6	L7
A1	80.1	84.0	81.6	86.0	86.4	86.2	86.0
A2	89.5	86.2	87.8	88.8	88.6	89.2	88.7
B1	86.7	75.4	83.8	82.9	84.1	85.6	88.8
B2	88.1	88.2	87.7	88.0	88.5	87.7	88.7

Table 5. 10 m noise level

Location	L1	L2	L3	L4	L5	L6	L7
A1	76.1	79.9	77.5	81.9	81.9	82.1	81.8
A2	85.2	82.2	83.4	84.8	84.7	85.2	84.7
B1	81.7	71.2	78.8	77.9	79.1	81.6	83.8
B2	83.2	84.0	83.0	83.4	83.9	83.1	84.2

Table 6. 15 m noise level

Location	L1	L2	L3	L4	L5	L6	L7
A1	72.0	76.1	72.5	77.7	78.1	78.1	77.8
A2	81.5	78.2	79.5	80.8	80.6	81.2	80.8
B1	76.7	67.4	73.8	73.0	74.1	76.6	78.7
B2	78.2	79.2	78.8	79.0	79.6	78.7	79.7

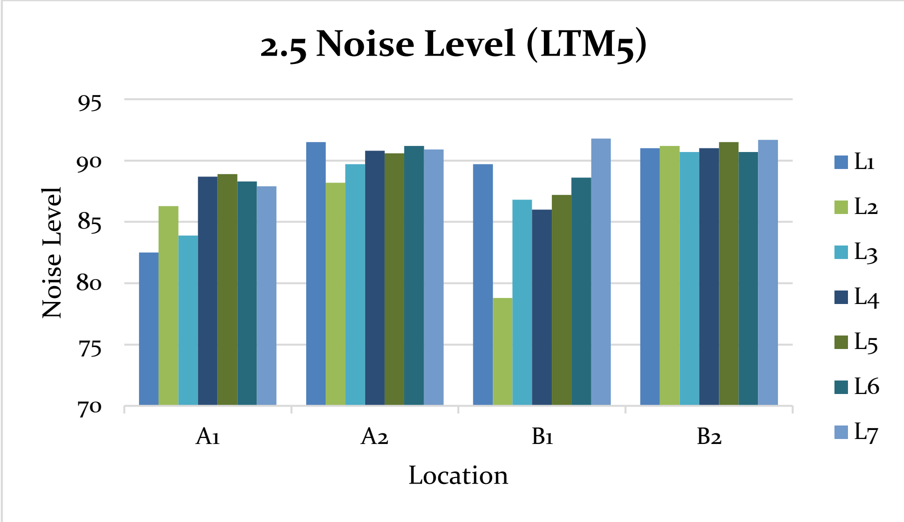

Figure 1. 2.5 m noise level (LTM5)

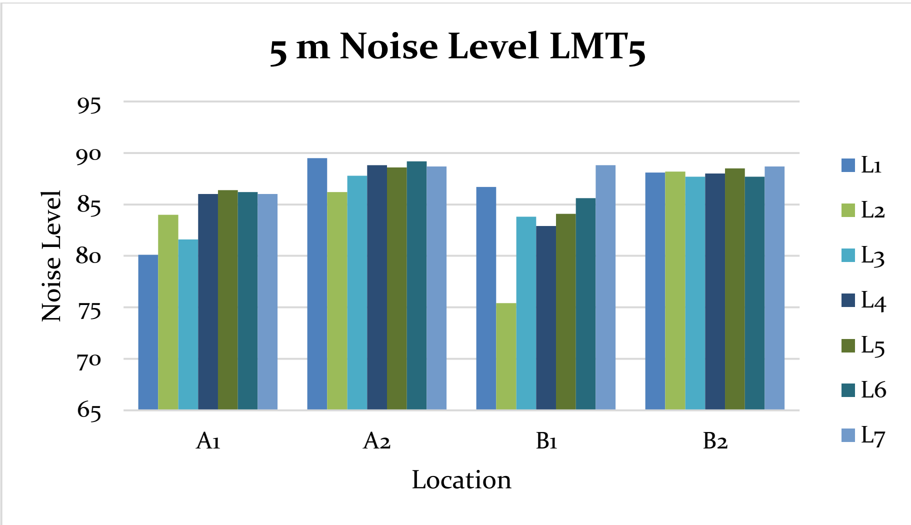

Figure 2. 5 m noise level (LTM5)

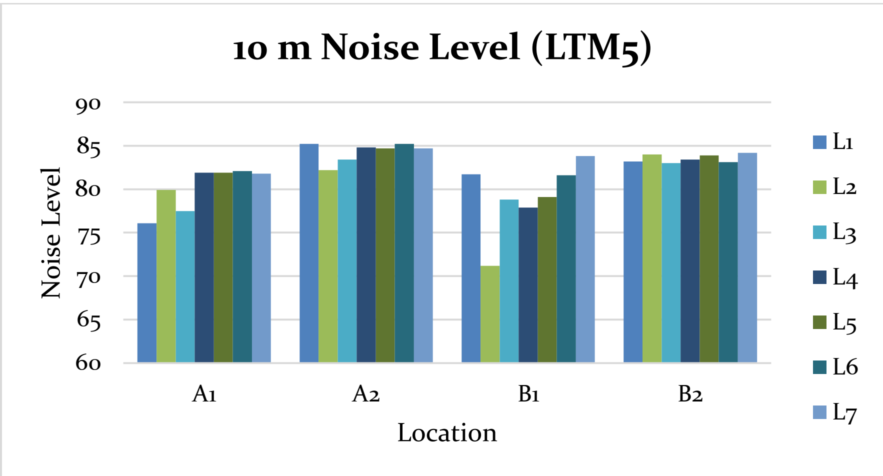

Figure 3. 10 m noise level (LTM5)

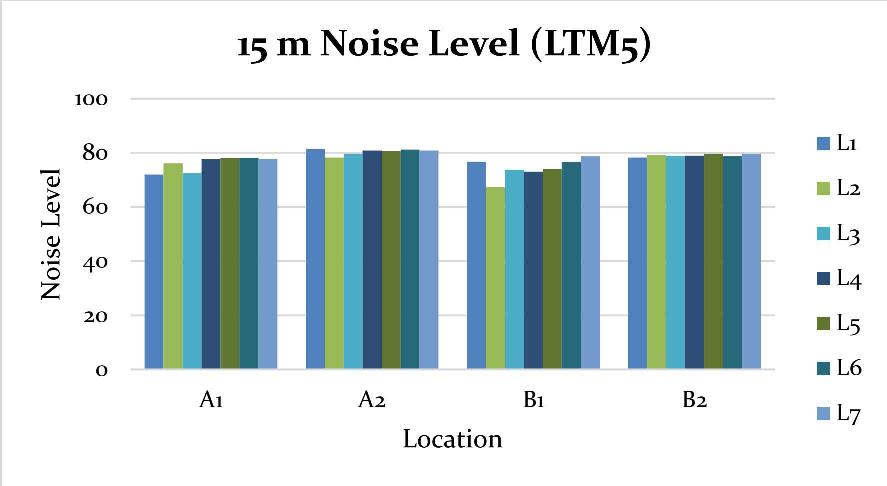

Figure 4. 15 m noise level (LTM5)

The results of measurements and calculations of the LTM5 noise level are equivalent to the noise level of each train that passes on the JPL 05 railroad, Jl. Kaligawe, Semarang shows that the noise level at a distance of 2.5 m ranges from 92 dB, at a distance of 5 it reaches 90 dB, at a distance of 10 m it reaches 85 dB while at a distance of 15 m it reaches 82 dB as the highest noise level. Based on the results of the calculation of the noise level, it is known that the noise level at locations A2 and B2 is bigger and has quite a difference from the noise level at locations A1 and B1. In addition, the results of measurements and calculations of noise levels show that the noise level at night is relatively higher than during the day. The noise levels of A2 and B2 are higher and far different from the noise levels of A1 and B1 which are assumed to be caused by different location conditions. Locations A2 and B2 are locations close to roads that cross the railroad tracks, so at those locations, there are sirens from loudspeakers as a sign that the train is passing through residential areas on the railroad tracks. Meanwhile, locations A1 and B1 are far from loudspeaker sirens and sirens from the main road, but only in residential areas.

The noise level when compared with the Noise Quality Standards in the PermenLH No. 48 of 1996 exceeds the noise quality standard, which exceeds 55 dB for residential areas. This can hurt the residents of the surrounding settlements because they have poor environmental quality due to one of the factors, namely noise. Meanwhile, when compared with the Noise Quality Standards in the NIOSH REL (National Institute for Occupational Safety and Health Recommended Exposure Level) exceeds the noise quality standard, which exceeds 85,57 dB with 7.02-hour of exposure. These two comparisons show that the noise level at the location is beyond quality standards for both standards. PermenLH No. 48 of 1996 is the national standard from Indonesia, meanwhile NIOSH REL one is the international standard. Through Permen LH No. 48 of 1996, it can be seen that the noise level at the study site exceeds the quality standards based on the designation of the area, namely the residential area. While NIOSH REL showed noise levels exceeding quality standards based on exposure duration, the length of exposure at the site reached 7.02 hours with an allowable policy of 85.57 dB. This result shows that if the number of trains passing by is increased, the quality standard of the next noise level depends on the length of noise exposure.

For noise modeling, there are several steps that need to do to make a noise contour. The maximum noise level for each distance is used as a value that represents the constant noise level at the location. The maximum LTM5 noise level data is then processed using *surfer software* along with inputting location point coordinates that have been converted from DMS coordinates to DD. The input data entered is the highest LTM5 noise level, each time interval, and distance for each location. The noise level at the location can be seen below through the figure graphics, for 2.5 m noise level, 5 m noise level, 10 m noise level, and 15 m noise level. Through this figure, can be seen noise level conditions at the location for each interval for each distance.

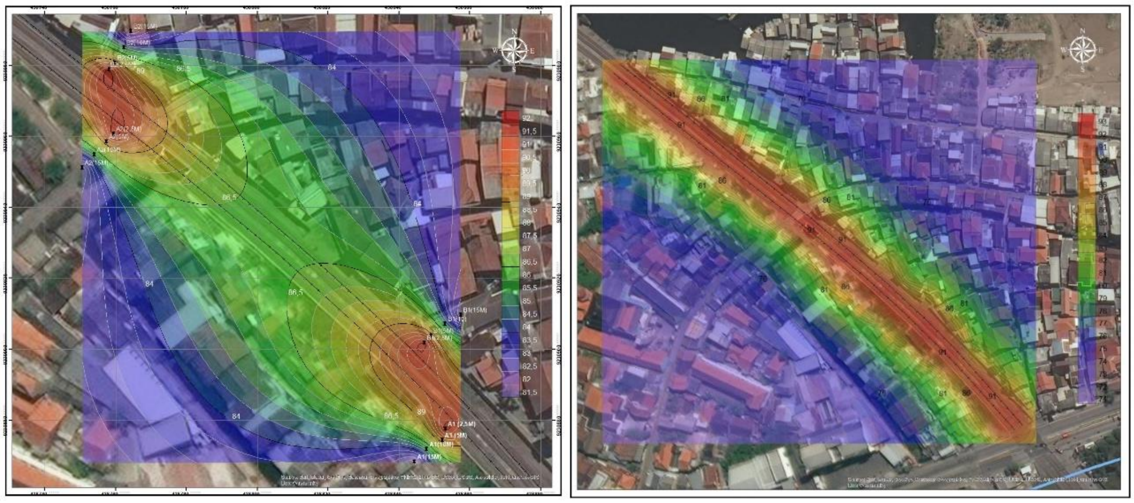

Figure 5. Noise level in location

Figure 5., show that all of the noise level points are on the red line, which means the noise level at Tambakrejo Village is in a bad condition and can be dangerous for the people. This study and research result shows that the previous statement of the noise level at Semarang is beyond the standard (Pusarpedal Laboratory and the Ministry of Environment and Forestry of the Republic of Indonesia, 2012) is true. This noise level shows the need for noise reduction efforts or other controls in order to ensure the safety and health of residents living in the JPL 05 Kaligawe railroad settlement, Semarang. This case can be developed and used as a reference in noise reduction planning and design.

4. Conclusions

Sampling results show up that the settlements have a noise level rate of 91.8 dB at a distance of 2.5 m, 89.5 dB at 5 m, 85.2 dB at 10 m, and 81.5 dB at 15 m. According to NOISE REL regulation, the maximum noise level allowed is 85.57 dB during 421 minutes or 7.02-hour exposure. This sampling result shows up that the noise level is beyond quality standards both NIOSH REL and PermenLH No. 48 1996 said noise level for settlements is allowed at 55 dB.

As a consideration, with noise levels exceeding 80 dB – 85 dB after the installation of the barrier concerning NIOSH REL Exposure and Duration, the possible impact or relationship of noise levels with public health is anxiety, malaise, hearing saturation, symptoms of gastric and circulatory pain, if excessive can occur heart disease, high blood pressure, and abdominal injuries.

However, by referring to NIOSH REL Exposure and Duration, the above symptoms may be unlikely because the noise from train activities at the design site does not last for 24 hours, but rather 7.02-hours with the maximum noise level after the installation of the barrier is 85.2 dB with a maximum allowable limit of 85.57 dB.

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