Mapping of Noise Contours due to the Production Process of Bolts and Nuts in the Production Department and Residences Environment of Pasir Angin Village, Cileunsgi, Bogor Regency

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Abstract. The physical work environment is an environmental situation that can affect the physicality of the worker. One of the disturbances in the physical work environment is noise. Noise can cause hearing damage if the duration of exposure and the noise level has passed the threshold value. One of the poor effects of noise received by workers is hearing health problems. The research location is in a manufacturing company that produces nuts and bolts, where their production activities cause noise, especially in the manufacturing process of the head of the bolt. The noise generated is heard in the production area and has spread to the community around the company. Therefore, it is necessary to conduct noise mapping to determine the propagation of noise in the production area and the community around the company. The results showed that the noise propagation in the production area is minimum 90.2 dB and maximum of 92.3 dB. Indicates that the noise generated by production activities at the company exceeds the threshold value (85 dB). Meanwhile, the noise propagation in the residents around the factory is minimum 66.5 dB and maximum of 78.5 dB. So, it shows that the noise received by residents exceeds the threshold value (55 dB). Keywords: Noise, Contour Zone, Environment.

INTRODUCTION

The work environment is one of the factors that affect a worker's productivity level in the work process. Other things that need to reck besides the optimal material flow is the comfort of working concerning the environment. One example is the noise level received by workers and residents.

According to the Decree of the Minister of Manpower KEP-51/MEN/1999, noise is any unwanted sound that comes from production process equipment or work tools that are at a certain point which can cause hearing loss. The impact of noise can occur if a person is exposed to more than the noise intensity set by the Ministry of Manpower in the production floor is not more than 85 dB [1]. For the convenience of working, it is necessary to measure the spread of noise that occurred. Measurement of the deployment of noise carried out by mapping noise using a contour zone, which will adjust with the Noise Level Quality Standard in KEP.48/MENLH/11/1996, for the community environment is not more than 55 dB [2]. Noises or sounds that the listener does not want, where the sound can distract, interfere with activities, can cause danger during daily activities can be called noise. Noise at a certain level that comes from the sound of work tools in the production process can cause health and comfort to be disturbed [3]. At the same time, the sense of hearing picks up noise from sound vibrations from various sound sources. The ear in one duration receives several sound waves with different frequencies [4]. The research location is a manufacturing company that produces various bolts and nuts types. In the manufacturing process, the machines used by the company have continuous noise, and it is received every day by workers in the production area and the surrounding community where the company
carries out its production process. The current condition of the noise level in the production area and the surrounding community has never been measured. It is not known whether the noise is still within the required threshold value or not, both in the production area and in the community around the company.

Current working conditions, most of the workers in the production area do not care about the impact of noise exposure, can be seen in their ignorance of using hearing protection equipment. Many machines operate and produce sound with different sound levels, but the hearing protection equipment used is the same for the entire production area. So that the noise received by workers is still within the threshold value, it is necessary to consider the noise attenuation value of each device according to the noise generated in the area. Although now compensation for nuisance permits has been carried out by the company to the surrounding community, it is necessary to socialize the procedure or calculation of compensation money. The reason is that the large number of demands filed by the surrounding community regarding the compensation money they had to receive from the company. The need to conduct noise mapping is to determine the pattern of noise distribution that occurs. The software is used to make a contour map called Surfer, a simple program to generate noise curves (noise contours) spatially for the location of potentially hazardous areas. In theory, the impact of noise itself varies, such as hearing loss, which causes temporary deafness and even permanent deafness, health problems such as psychological disorders (coronary heart disease, stress, fatigue), and physiological disorders (increased blood pressure, blood vessel construction, increased pulse, sensory disturbances) and balance disorders [5]. The poor impact that often occurs if workers are attached to noise for too long is the effect on hearing, which can cause deafness, but using hearing protection devices can control the noise. Another interest in doing this noise mapping is to classify the noise level, which will later determine the amount of compensation money and received by residents around the factory.

Based on the above, this research will carry out noise mapping activities in the production area and the community around the factory, then the results of this mapping will be disseminated to the company and the community to be used as input for future improvements.

**Literature Review**

*Threshold Values of Noise*

The noise threshold value that is safe and permitted by the Ministry of Manpower is 75 dB, with workers working time of 8 hours/day or 40 hours/week. Each noise has an area that is divided according to the noise points that are permitted by the Ministry of Environment as regulated in KEP-48/MENLH/11/1996 [2], there are:

1. Zone A: Intensity 35-45 dB. Zones designated for research sites, health/social care places.
2. Zone B: Intensity 45-55 dB. Zones designated for housing, public area, and places of worship.
3. Zone C: Intensity 55-65 dB. Zones designated for offices, public facilities, and markets.
4. Zone D: Intensity 65-75 dB. Zones designated for industries, recreation, terminals, and factories.
5. Other zones (transportation): An intensity of more than 75 dB.

*Noise Level Calculation*

The ways to calculate the noise standard level according to the ministry of environment KEP-48/MENLH/11/1996 divided into three times [2], as follows:

1. Noise level during the daytime (Ls), for 16 hours between 06.00 - 22.00. The formula as follows:
   \[ Leq_{\text{daytime}} = L_s = 10 \log \frac{1}{16} \sum t_i 10^{0.1l_i} \text{dB} \]  
   \( L_s \) is daytime noise level (dB), \( t_i \) is measurement time interval, and \( l_i \) is Leq averages at a certain time interval.

2. Noise Level at Night (Ln), for 8 hours between 22.00 - 06.00 with a minimum of data collection for 3 measurements with a certain frequency range. The formula as follows:
   \[ Leq_{\text{nighttime}} = L_n = 10 \log \frac{1}{8} \sum t_i 10^{0.1l_i} \text{dB} \]  
   \( L_n \) is night noise level (dB), \( t_i \) is interval of measurement, and \( l_i \) is Leq averages at a certain time interval.

3. Noise Levels During Day and Night (Lsm). Daytime to nighttime noise levels is used to find out whether noise has exceeded the noise level from field measurements or not. The formula as follows:
   \[ L_{sm} = 10 \log \frac{1}{24} \left( 16 \cdot 10^{0.1s/10} + 6 \cdot 10^{(0.1m+5)/10} \right) \text{dB} \]
L_{sn} is value of noise level during day and night, L_{d} is value of noise level during daytime, and L_{m} is value of noise level during the night.

**Contour Map**

A contour map is a type of map that uses contour lines to illustrate the height of an area on the earth's surface. Contour lines are imaginary lines that are usually used on maps and represent elevation points on the earth's surface. Contour lines in absolute terms provide information about the height measured from the mean surface plane [6]. The entire shape of the earth's surface can be depicted using contour lines on the map if some of the contour lines drawn have different heights. These contour lines are a series of dots forming a closed winding line. Usually, a line representing a lower altitude is circling a higher altitude line. The height lines do not intersect and branch off. In a steep location, the elevation lines are drawn closer together, while in sloping areas the elevation lines that are formed will be far apart [7].

**Surfer Software**

Surfer is a contouring and 3D surface mapping software, surfer used for making contour maps and three-dimensional modeling. Surfer program that runs under Microsoft Windows, and does not require high hardware or operating systems. The Surfer software quickly and easily converts the data into outstanding contour.

**HO (Hinder Ordinance)**

Disturbance Permit or Hinder Ordonnantie (HO) is a business activity permit from the City Government that must be owned by any business actor whose place or business activity has the potential to cause certain disturbances, dangers, inconveniences, or losses. If the company causes harm to the surrounding community, it is obliged to pay a fee to obtain a HO. Based on the Regulation of the Mayor of Bogor No. 20/2013, the structure of the Bogor city, the formula is divided into two.

\[
\text{HO} = 50 \text{m}^2 \times \text{business area} \times \text{location index} \times \text{disturbance index} \times \text{Rp 1,000} \quad (5)
\]

\[
\text{HO} = \text{business area} \times \text{location index} \times \text{disturbance index} \times \text{Rp 1,400} \quad (6)
\]

**Noise Reduction Rate**

Noise reduction rate is a measure of the ability of a hearing protector to reduce noise levels [8]. This is the methods to calculate NRR according to The United States Occupational Safety and Health Administration (OSHA), as follows.

\[
\text{NRR}_{\text{actual}} = (\text{NRR}_{\text{label}} - 7) \times 50\% \quad (7)
\]

NRR actual is actual noise reduction level, NRRlabel is the level of noise reduction seen on the packaging tool label, value of 7dB is determination of noise reduction using hearing protection devices, and 50% is average safety provisions used [8].

**METHODS**

The methods section of a research paper is the most important because it provides the procedures’ of the study. The method is divided into 3 stages, the stages explain belows.

1. Perform the noise mapping based on contour maps using GPS, consisting of work areas and residential areas, the steps are: calculate noise equivalent during the daytime, night-time, day-night equivalent. The data used is noise level from the daytime, night-time, day-night equivalent.
2. Performing noise mapping with the contour zone method using Surfer to determine the spread of noise that occurs. The data used is the result of the calculation of the equivalent noise level. Mapping of these possibilities will result in risk leveling so that later it will be determined what actions must be taken so that these risks can be minimized. The results of the mapping are obtained by multiplying the value of the possibility of a risk occurring with the severity level that is accepted if the risk does occur.
3. Calculate the reduction value of hearing protective equipment used by workers, properly and correctly, by calculating the noise reduction value of hearing protective equipment used by workers, as well as calculating the compensation fee (HO) that must be paid by the company to the government.

RESULTS AND DISCUSSION

Measurement of GPS

Before measuring the noise value using a sound level meter, the GPS coordinates were taken at the location where the noise value was taken. The GPS coordinates collected during the study are shown in table 1.

<table>
<thead>
<tr>
<th>Point Coordinate</th>
<th>GPS Coordinate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>S6 23.450 E106 58.757</td>
</tr>
<tr>
<td>2</td>
<td>S6 23.449 E106 58.741</td>
</tr>
<tr>
<td>3</td>
<td>S6 23.452 E106 58.749</td>
</tr>
<tr>
<td>4</td>
<td>S6 23.451 E106 58.758</td>
</tr>
</tbody>
</table>

Measurement of Noise Value in The Community Environment

Data were collected in community settlements around the company, data collecting using a noise measurement tool is Sound Level Meter.

In data collection, there were four noise measurement points in different areas. Area 1 is a community settlement located in the western part of the factory, Region 2 is a location of community settlement on the north side of the factory on the left, Region 3 is a community settlement located on the north side of the factory on the right side, and Area 4 is a location of community settlement in the eastern part of the factory. Of the four areas, Sound Level Meter is placed 3 and 6 meters apart from the outer boundary of the factory with a height of 1 meter. The following is an illustration of the description of data collection points in the three regions.
Measurement of Noise Value in Production Area

Production Department Noise Mapping

Noise data were taken from six points, scattered in the production area with the timing of data collection following the Decree of the State Minister for the Environment no. KEP-48/MENLH/11/1996 performed several calculation processes to obtain the average noise value, namely data uniformity test and data frequency distribution. The following is a calculation of the noise data described below.

a. Calculation of Uniformity Test and Frequency Distribution of Noise Data

To find out whether the data collected in the study are data sourced from one system, it is necessary to test data uniformity. The uniformity test of the noise value data uses a 95% confidence level and an accuracy level of 5%.

<table>
<thead>
<tr>
<th>Time of Retrieval of Data</th>
<th>The Calculation Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data Uniformity Test</td>
</tr>
<tr>
<td>(L1)</td>
<td>Uniform Data</td>
</tr>
<tr>
<td>(L2)</td>
<td>Uniform Data</td>
</tr>
<tr>
<td>(L3)</td>
<td>Uniform Data</td>
</tr>
<tr>
<td>(L4)</td>
<td>Uniform Data</td>
</tr>
<tr>
<td>(L5)</td>
<td>Uniform Data</td>
</tr>
<tr>
<td>(L6)</td>
<td>Uniform Data</td>
</tr>
<tr>
<td>(L7)</td>
<td>Uniform Data</td>
</tr>
</tbody>
</table>

b. Calculating the Equivalent Continuous Noise Level

The results of calculating the average noise value at each point and each time condition are used to calculate the equivalent noise level. A summary of the calculation of the Equivalent Continuous Noise Level at all data collection points is shown in Table 3.

<table>
<thead>
<tr>
<th>Point of</th>
<th>Equivalent Continuous Noise Level (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Daytime</td>
</tr>
<tr>
<td>1</td>
<td>90,53</td>
</tr>
<tr>
<td>2</td>
<td>91,30</td>
</tr>
<tr>
<td>3</td>
<td>91,35</td>
</tr>
<tr>
<td>4</td>
<td>91,83</td>
</tr>
<tr>
<td>5</td>
<td>91,53</td>
</tr>
<tr>
<td>6</td>
<td>90,90</td>
</tr>
</tbody>
</table>

c. Production Area Noise Contour Map

Before making a contour map using Surfer Software, the GPS coordinate points that have been collected during the research are converted into x, y and z coordinates where x and y are GPS coordinates, while z is the average value of noise in each point at the entire time of data collection. The following data will be processed in the Surfer Software as listed in Table 3. After entering the x, y and z data in the Surfer Software the data can be processed to create noise contour maps and maps in 3D as shown in Figures 2 and 3.
FIGURE 2. Noise Contour Map of the Company's Production Area

From the results of noise mapping with contour maps, it can be seen that in the production room the company has a noise level above the predetermined threshold of 85 dB so that workers in the production area are required to wear ear protection. The noise distribution appears to have different levels marked by white coloring for the highest noise level, namely 92.4 dB to the lowest noise level of 90.2 dB in the production area which is marked with purplish blue.

FIGURE 3. 3D Shape Noise Map of Production Area

The results of the 3D noise map of the production area illustrate that at the first point the data collection has the lowest noise value distribution compared to other data collection points. Meanwhile, some areas of the sixth point of noise data collection have the highest noise exposure, namely 92.3 dB. At the second to the fifth point of noise data collection, it is clear that the spread of noise in the surrounding environment increases.

d. Hearing Protection Device Reduction Level

The company provides hearing protection equipment in the form of earplugs for production area workers to minimize noise received by workers. The following is a calculation of the actual noise reduction level with the use of a single personal protective equipment. The hearing protection device proposed for use by company workers is an earplug with a Noise Reduction Rate of 25 dB.

\[
\text{NRR}_{\text{actual}} = (\text{NRR (Label)} - 7 \text{ dB}) \times 50% \\
= (25 - 7) \times 50% \\
= 18 \text{ dB x 50%} \\
= 9 \text{ dB}
\]
Calculation of Noise Value in The Community Environment around The Company

Residential Environment Noise Mapping

Before doing noise mapping, it is necessary to calculate the noise level values in each area. The following is a calculation of the noise data described below.

a. Noise Mapping in the Residential Environment

<table>
<thead>
<tr>
<th>Area</th>
<th>L1</th>
<th>L2</th>
<th>L3</th>
<th>L4</th>
<th>L5</th>
<th>L6</th>
<th>L7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 1 - 3 Meters</td>
<td>77.6</td>
<td>78.2</td>
<td>77.3</td>
<td>78</td>
<td>78</td>
<td>78</td>
<td>78.9</td>
</tr>
<tr>
<td>Area 1 - 6 Meters</td>
<td>68.4</td>
<td>69</td>
<td>68.2</td>
<td>68.8</td>
<td>69</td>
<td>69</td>
<td>68.8</td>
</tr>
<tr>
<td>Area 2 - 3 Meters</td>
<td>77.9</td>
<td>78.6</td>
<td>78</td>
<td>77.7</td>
<td>78.4</td>
<td>77.9</td>
<td>77.5</td>
</tr>
<tr>
<td>Area 2 - 6 Meters</td>
<td>68.7</td>
<td>69.3</td>
<td>68.9</td>
<td>68.5</td>
<td>69.1</td>
<td>68.8</td>
<td>69</td>
</tr>
<tr>
<td>Area 3 - 3 Meters</td>
<td>78.5</td>
<td>79.0</td>
<td>78.4</td>
<td>79</td>
<td>78.1</td>
<td>78.7</td>
<td>77.4</td>
</tr>
<tr>
<td>Area 3 - 6 Meters</td>
<td>69.3</td>
<td>69.7</td>
<td>69.2</td>
<td>69.8</td>
<td>69.0</td>
<td>69.4</td>
<td>68.3</td>
</tr>
<tr>
<td>Area 4 - 3 Meters</td>
<td>78.5</td>
<td>78.9</td>
<td>78.4</td>
<td>78.6</td>
<td>78.2</td>
<td>78.5</td>
<td>78</td>
</tr>
<tr>
<td>Area 4 - 6 Meters</td>
<td>69.2</td>
<td>69.6</td>
<td>69.2</td>
<td>69.4</td>
<td>69.0</td>
<td>69.2</td>
<td>68.8</td>
</tr>
</tbody>
</table>

b. Calculating Daytime (Ls) and Nighttime (Lm) Equivalent Noise Levels

After processing the data to calculate the Noise Value in each region, the following results are obtained.

<table>
<thead>
<tr>
<th>Area</th>
<th>Noise Value (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area 1 - 3 Meters</td>
<td>80</td>
</tr>
<tr>
<td>Area 1 - 6 Meters</td>
<td>70.1</td>
</tr>
<tr>
<td>Area 2 - 3 Meters</td>
<td>80.1</td>
</tr>
<tr>
<td>Area 2 - 6 Meters</td>
<td>71</td>
</tr>
<tr>
<td>Area 3 - 3 Meters</td>
<td>80.5</td>
</tr>
<tr>
<td>Area 3 - 6 Meters</td>
<td>71.3</td>
</tr>
<tr>
<td>Area 4 - 3 Meters</td>
<td>80.5</td>
</tr>
<tr>
<td>Area 4 - 6 Meters</td>
<td>71.3</td>
</tr>
</tbody>
</table>

Referring to the Decree of the Minister of Environment No.48 of 1996, the noise value in all areas exceeds the Threshold Value (NAB) for settlements, which is 55 dB. So, the Noise Value in all regions is in high category.

c. Contour Zone Mapping

After knowing the Noise Value data in each region, then the data is processed into the Surfer Software to create a contour zone mapping.

FIGURE 4. 3D Contour Map Results
X and Y data are data obtained from the coordinates of each area using GPS, Z data are data obtained from the calculation of the average noise that has been done. Following are the results of the Contour Map on the community settlements around the company using the Surfer Software. Based on the results of the contour map above, all areas in the community settlements around the company are colored red. With a maximum noise value of 78.5 dB and a minimum noise value of 66.5 dB. This value exceeds the Threshold Value, which is 55 dB. Therefore, the company is obliged to provide compensation to the community following the applicable Bogor Regency regulations. In addition, the company also needs to make improvements so that the noise exposure affecting the community is reduced.

d. Value of Company Compensation
The fees that must be paid by the company to the local government treasury, in this case:
Total Compensation Value = Rp. 750,000,- + Rp. 3,375,000,- = Rp. 4,125,000,-
The administrative and financial settlement of the disturbance permit shows that the company is fit to run its operations, the company and the community need to conduct socialization activities related to compensation due to noise generated, of course, this is related to the payment scheme to the surrounding community considering the disturbance permit that has been issued.

CONCLUSIONS

Based on the results of data processing and analysis has been done, it can be concluded that the results showed that the noise propagation in the production area is minimum 90.2 dB and maximum of 92.3 dB. Indicates that the noise generated by production activities at the company exceeds the threshold value (85 dB). Meanwhile, the noise propagation in the residents around the factory is a minimum of 66.5 dB and a maximum of 78.5 dB. So, it shows that the noise received by residents exceeds the threshold value (55 dB). The reduction value of hearing protection equipment used by workers at a distance of 3 meters and 6 meters with earplugs and earmuffs in day time or night time conditions in the production area is 9 dB, and the compensation cost that must be paid by the company to the local government of Bogor Regency is Rp. 4,125,000,-.

Further research can socialize the use of ear protective equipment properly and correctly, and conduct socialization with expert doctors regarding hearing health problems.

REFERENCES