The Analysis of Noize Hazard towards Workers in Booster Pump Location of PDAM Tirtanadi Medan, Indonesia

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Abstract. The noise sound can be potentially arisen by the usage of machine and work tools that support the production process. PDAM Tirtanadi is a company runs provincial water supply engaged in the drinking water processing. However, the machine and tools of the company can generate the noise. Thus, the paper aims to find out the noise intensity of 5 points measurement in booster pump, then determines the correlation towards communications disruption, psychology and physiology. Then, the sound pressure level measurement method refers to Indonesian Minister of the Environment Decree Number 48 Year 1996, and the sound level meter was utilized as means for the research. The result shows that the noise intensity gained of 5 points passed the noise Threshold Limit Value (TLV) as much 96.40dB – 96.75dB. Moreover, the noise level has a significant influence towards the communications, psychology and physiology disruption, which the R value of multiple correlation as much as 0.884.

1. Introduction
Noise is sound pollution that disturbs or endangers health, and even it can be disrupted to psychology, physiology, and even communication [1], [2]. The disorders are classified in the form of auditory disorders (hearing disruption) and non-auditory disorders (communication, physiology, and psychology) [3]. PDAM Tirtanadi is a provincial water supply enterprise in Medan, Indonesia which engaged in drinking water treatment using noise-generating machinery and work equipment. Noise control efforts include identifying noise problems in the booster pump area and determining the noise level received by workers.

Furthermore, noise problems from the booster pump machine location resulting a high value of sound level, namely between 88 dB to 93 dB. The intensity of the sound range have passed the noise threshold values that have been allowed for the industrial category in accordance to Indonesian Minister of Manpower and Transmigration Decree. Hence, the problem will causing deafness effects and negative disturbances such as interference with communication, physiology and psychology. Disorders that are often experienced by workers on a booster pump are the presence of frequent headaches, insomnia, fatigue, muscle tension, shortness of breath and others.

The paper goals to discover the noise intensity 5 measurement points located on the booster pump of PDAM Tirtanadi. Other than that, the study also determines the correlation between noise level towards communications, psychology and physiology disruption. The paper is the resume of the study by researcher [4] with more evaluation and modification.
2. Noize Hazard

Sounds are mechanical vibrations in the air or solid objects that can still be captured by normal human ears, with a frequency range between 20-20,000 Hz. The sensitivity of the human ear to this range is narrowing with human ages. Below that range is called infrasound, while above that range is called ultrasound. Meanwhile, the voice is human sound. Airborne sound is the sound that propagates through the air. Sound structure is the sound that spreads through the construction of a building [5]. Indonesian Minister of Manpower and Transmigration issued a regulation Number /PER.13/MEN/X/2011, regarding allowable noise threshold value in time per day. The regulations are illustrated in Table 1.

Table 1. Threshold Limit Value (TLV) by Minister of Manpower and Transmigration.

| Exposure time per day | Noise intensity (dB) |
|-----------------------|----------------------|
| 8 hours               | 85                   |
| 4 hours               | 88                   |
| 2 hours               | 91                   |
| 1 hour                | 94                   |
| 30 minutes            | 97                   |
| 15 minutes            | 100                  |
| 7.5 minutes           | 103                  |
| 3.75 minutes          | 106                  |
| 1.88 minutes          | 109                  |
| 0.94 minutes          | 112                  |
| 28.12 seconds         | 115                  |
| 14.06 seconds         | 118                  |
| 7.03 seconds          | 121                  |
| 3.52 seconds          | 124                  |
| 1.76 seconds          | 127                  |
| 0.88 seconds          | 130                  |
| 0.44 seconds          | 133                  |
| 0.22 seconds          | 136                  |
| 0.11 seconds          | 139                  |

Based on Table 1, maximum exposure times of noise per day are 8 hours with noise intensity as much 85 dB. Then, by monitoring the working environment from 2002 to 2005 conducted in Korea Incheon found noise levels exceeding TLV in the work environment. The proportion of noise in the work environment that exceeds the threshold value in 2002 is 22.9% and 23.9%, whereas in 2005 the percentage of sound was 28.7% and 19.3%. The noise inspection data in the last four years states that the average noise level is between 84 dB and 86 dB. The proportion of cases of noise levels between 80 dB to 90 dB is 64.6%. While the percentage of cases of noise exceeding 100 dB is 1.3%. The proportion of cases below 80 dB is 11.1% [6].

The effects of noise can be psychological effects, such as being surprised, unable to concentrate, effects on communication, increase in blood pressure, ear pain, and also able to loss of hearing ability (deafness) [7]. In this study, the disruptions are divided into three categories, namely: psychological, physiological, and communication disruption. In term of psychological, noise can be causing discomfortable situation, lack of concentration, insomnia, and irritability. When noise is received for a long time it also can cause psychosomatic diseases such as gastritis, stress, and fatigue. A very high noise can cause floating thoughts, which can cause physiological disturbances in the form of dizziness or nausea. Noise also can cause disruption of work, up to the possibility of errors because they do not hear a signal or alarm. Thus, communication disruption is occurred due to noise hazard.
3. Methodology

3.1. Tools and Conceptual Model

The tools that used in this study are Sound Level Meter to measure noise levels, and a meter gauge to measure the distance taking of each noise level measurement point. Figure 1 shows conceptual model of the research.

Data were obtained from the measurement results as well as from the company record file are processed quantitatively in order to obtain a representative image of the data to support the resolution of noise problems in the production unit at PDAM Tirtanadi.

The steps for processing data are as follows:

1. Noise level recapitulation (dB).
2. Calculate the equivalent noise level \( L_{eq} \) by using the formula as:

\[
L_{eq} = 10\log \left( \frac{1}{16} \{ T1 \cdot 10^{0.1L1} + \ldots + T3 \cdot 10^{0.1L3} \} \right) \text{ dB (A)}
\]  

Where:
- \( L_{eq} \) = Equivalent noise level in dB (A).
- \( L \) = Sound pressure level.
- \( T \) = time period.
3. Calculate of sound intensity using the formula as:

\[
L_i = 10\log \left( \frac{1}{10} \right) \text{ dB}
\]  

Where:
- \( T1 \) = Maximum exposure time per day allowed (hours).
- \( 8 \) = Number of working hours per day allowed (85 dB).
- \( 3 \) = A number that shows the relationship between noise intensity and the noise level (Exchange rate).
4. Determine the maximum exposure time allowed, with the formula as:

\[
T1 = \frac{8}{2(L_{eq} - 85)/3}
\]  

Where:
- \( I \) = Sound intensity at distance \( r \) from sound source (watt/m²).
4. Result and Discussion

4.1. Noise level recapitulation (dB)

The results of noise level measurements carried out at 5 location points in the area of the booster pump machine are as follows:

| Measurement Point | Noise Level (dB) | Measurement Time |
|-------------------|------------------|------------------|
|                   | 08.00            | 11.00            | 14.00            |
| 1                 | 92.91            | 90.99            | 88.73            |
| 2                 | 93.01            | 90.97            | 88.69            |
| 3                 | 93.01            | 90.92            | 88.68            |
| 4                 | 92.92            | 90.91            | 88.57            |
| 5                 | 92.99            | 90.90            | 88.64            |

4.2. Calculation of the equivalent noise level \( (L_{eq}) \)

\[
L_{eq} = 10 \log \left\{ \frac{1}{16} \left( T1.10^{0.1/L1} + \ldots + T3.10^{0.1/L3} \right) \right\} \text{ dB (A)}
\]

\[
L_{eq} = 10 \log \left\{ \frac{1}{16} \left( 3.10^{0.1/92.91} + 2.10^{0.1/90.99} + 3.10^{0.1/88.73} \right) \right\}
\]

\[L_{eq} = 96.75 \text{ dB}\]

Therefore, after calculation, the recapitulation of \( L_{eq} \) calculation is obtained at 5 measurement points as shown in Table 3.

| Measurement Point | Noise Level (dB) Equivalent \((L_{eq})\) |
|-------------------|-----------------------------------------|
| 1                 | 96.75                                   |
| 2                 | 96.40                                   |
| 3                 | 96.41                                   |
| 4                 | 96.42                                   |
| 5                 | 96.57                                   |

4.3. Sound intensity calculation

The calculation is performed by using equation (2), and for example Point 1 has the \( L_{eq} \) value as much as 96.75 dB.

\[
96.75 = 10\log \left( \frac{1}{10^{-12}} \text{ W/m}^2 \right)
\]

\[= 10^{2.325} \text{ W/m}^2\]
Table 4. Sound Intensity Data at 5 Measurement Points.

| Measurement Point | L_{eq} (dB) | I (W/m^2) |
|-------------------|-------------|------------|
| 1                 | 96.75       | 10^{2.325} |
| 2                 | 96.40       | 10^{2.359} |
| 3                 | 96.41       | 10^{2.358} |
| 4                 | 96.42       | 10^{2.343} |
| 5                 | 96.57       |            |

4.4. Determination of the maximum exposure time allowed

For each measurement point has a different noise level, so that at each measurement point also has a different maximum working / exposure time. The available noise level is 85 dB for an exposure time of 8 hours per day, so the exposure time is calculated using the following formula (3). Then, for example Point 1 has the L_{eq} value as much as 96.75 dB.

\[
T_I = \frac{8}{2(96.75 - 85)/3} = 1.02 \text{ hours}
\]

Table 5. Allowed Time for Maximum Exposure.

| Measurement Point | L_{eq} (dB) | TI (hours) |
|-------------------|-------------|------------|
| 1                 | 96.75       | 1.021      |
| 2                 | 96.40       | 1.052      |
| 3                 | 96.41       | 1.051      |
| 4                 | 96.42       | 1.050      |
| 5                 | 96.57       | 1.037      |

4.5. Multiple Correlation Analysis

Multiple correlation analysis is used to determine the relationship between two or more independent variables (X1, X2, ... Xn) to the dependent variable (Y) simultaneously. The value of R ranges from 0 to 1, the value getting closer to 1 means the relationship that occurs is getting stronger, and vice versa [8]. According to researcher [9], guidelines for providing interpretations of correlation coefficients as follows:

- 0.00 – 0.199 = very low.
- 0.20 – 0.399 = low.
- 0.40 – 0.599 = moderate.
- 0.60 – 0.799 = high.
- 0.80 – 1.00 = very high.

Table 6. Multiple Correlation Analysis (R) results.

| Model | R     | R Square | Adjusted R Square | Std. Error of the Estimate |
|-------|-------|----------|-------------------|---------------------------|
| 1     | .0884 | .781     | .672              | .68608                    |
5. Conclusion
The conclusions obtained based on the results of the analysis and discussions are as follows:
1. The noise level in the booster pump area of the Tirtanadi PDAM does not match the permissible threshold value of 85dB. While the results of the measurement of the noise level of the location of the noise values at points 1 to 5 are 96.75; 96.40; 96.41; 96.42; 96.57 dB as shown in Table 3.
2. The noise level has a significant effecting on communication, psychology and physiology disruptions, namely the R value of the multiple correlation tables 0.884 as shown in Table 6.

6. References
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