Work Rotation to Reduce the Effect of Noise Exposure for Operators in Sugar Factory

Anizar*, Erwin, R M Sari, K Syahputri and I Rizkya

Department of Industrial Engineering, Faculty of Engineering, Universitas Sumatera Utara, Padang Bulan Medan 20155, Indonesia

*anizar_usu@usu.ac.id

Abstract. This study investigates noise level at the grinding station in a sugar factory by measuring sound pressure level. This study aims to obtain noise level map, so that operators’ work hour can be regulated accordingly. Noise level is measured for four days using sound level meter. Observation is conducted at 9 points at 09.00, 11.00, 13.00, and 15.00 o’clock. The number of point of measurement is determined using contour mapping technique using grid size of 3m x 3m. Noise distribution pattern is obtained from surfer software v11.0. The results show that Daily Noise Dose (DND) exceeds the standard set by Occupational Safety and Health (OSHA). Every point of measurement has different noise level, which means that the maximum exposure duration allowed is also different. Maximum exposure duration allowed for the 9 points is ranging from 72.48 minutes to 143.54 minutes. This infers that the problem can be solved by work hour regulation of operators at each station; operators work for a different period of time at different stations.

1. Introduction
Sugar factory has production capacity of 4000 tons per day, which runs for 24 hours per day devided into 3 work shifts. During grinding process, grinding machine produces noise level of 95.1 dB, which exceeds the allowed upper limit for noise level. The allowed upper limit set by Indonesian Government of Human Resource and Transmigration Decree No 13 The Year 2011 is 85 dB, where as Occupational Safety and Health (OSHA) set the number to be 90 dB for 8 hours of work per day. Such noisy condition at grinding station causes operators to complain about communication problem that often happens, such as the need of speaking louder which is more tiring and information that is wrongly processed.

Study related to noise level in industrial environment can be found on some literatures. Most industries in developing countries face serious problems regarding noise and vibration. Noise pollution or simply called noise is considered as the most important problem in work environment, especially in industrial country and developed country. Noise pollution in industry is a source that can disturb daily activity of workers, both physically and mentally. Noise pollution is often underrated, as it cannot be seen, smelled or touched, even though its effect on human health is very dangerous. World Health Organization (WHO) admits that noise pollution is the 3rd world dangerous threat after water and noise pollution [1,2]. Development of infrastructure, house facilities, education, and transportation industry lead to an increase in noise pollution and temperature. Noise pollution in city area keeps increasing, since traffic and industrialization also increase. Mitigation steps can be taken by reducing the source of
noise. An effort to reduce noise exposure is by growing vegetations around factories and installing sound damper inside the factories [3]. Noisy industrial activities must be performed outside living area. In developing acoustic design for building, noise produced from the activities performed and its effect toward the environment should be considered [4]. Noise disturbs communication, reducing quality information received by workers [5]. This results in worker’s complaints, such as headache, inadequate sleep, and easily offended. At different location, workers will be exposed to different level of noise. Pearson correlation shows that noise level will decrease as the distance increases [6]. Noise exposure also induce exhaustion. Factors of work shift and old age also induce more exhaustion [7]. Noise level assessment in relation with its exposure and bad effect on factory workers need to be conducted to obtain its safe limit [8]. Noise level exceeding its allowed safe limit, 85 dB, is a main threat to health in work. Negative effect level of noise depends on its intensity, frequency spectrum characteristics, exposure duration, and individual sensibility [9].

2. Methods

Noise level measurement is conducted at grinding station in a sugar factory in Binjai, North Sumatera, Indonesia. This is a descriptive study, as it aims to describe the problem happening on the production floor and give corrective recommendation. Measurement is performed for four days at 09.00 – 16.00 o’clock. Measurement points of area with size of 3m x 3m is determined using reference of noise measurement made by European Commission Working Group Assessment of Exposure to Noise (WG-AEN). The 9 points of measurement is measured using sound level meter as shown in figure 1.

\[
\text{Leq} = 10 \log_{10} \left[ \sum t_j 10^{0.1L_j} \right] \quad (1)
\]

\[
\text{Ls} = 10 \log_{10} \left[ \frac{1}{4} \right] 10^{89.8/10} + \frac{1}{4} 10^{89.5/10} + \frac{1}{4} 10^{89.3/10} + \frac{1}{4} 10^{89.4/10} \quad (2)
\]

Each measurement represents a certain time interval, with L1 taken at 09.00 o’clock represents time interval of 08.00-10.00 o’clock, L2 taken at 11.00 represents time interval of 10.00-12.00 o’clock, L3 taken at 13.00 represents time interval of 12.00-14.00 o’clock, an L4 taken at 15.00 represents time interval of 14.00-16.00 o’clock. Noise level data at every point of measurement for 4 days are represented by equivalent noise level. Equivalent noise level is a number of single noise level showing sound energy equivalent to ever changing energy in a certain time interval. It is written mathematically as

Figure 1. Noise level measured points layout

In the next step, mapping is conducted to obtain noise distribution pattern on production floor using
surfer v.11.0 software [11]. The data used is total noise level on production floor by determining the coordinate of noise level measured points. Sound intensity is measured at 9 points, 4 times per day for four days [12],

\[ L_i = 10 \log \left( \frac{I}{I_0} \right) \text{dB} \]  

(3)

where \( L_i \) is sound intensity level (dB), \( I \) is sound intensity at a distance of \( r \) from sound source (\text{watt/m}^2), and \( I_0 \) is reference sound intensity (W/m^2). Sound energy emitted by sound source is then calculated using the following formula,

\[ I = \frac{w}{4\pi D^2} \text{W/m}^2 \]  

(4)

Different noise level obtain from different measured points cause maximum duration of exposure allowed per day also differ. It is calculated using the following formula,

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

(5)

where \( T_I \) is maximum duration of exposure allowed (hour), \( \text{Leq} \) is noise level (dB), the allowed work hour for noise level of 85 dB is 8 hours per day, with exchange rate of 3. Noise exposure is calculate using the following formula,

\[ D = \frac{c}{T_I} \times 100\% \]  

(6)

where \( D \) is Daily Noise Dose (DND), \( c \) is the actual exposure duration (hour), while \( T_I \) is the maximum exposure allowed per day (hour). NIOSH states that the criterion of safe dose is no larger than 100%.

3. Results and discussion

The average noise level measured at 9 points of measurement for four days at 09.00, 11.00, 13.00, and 15.00 is shown on table 1. The highest noise level is 95.4 dB and the lowest is 87.5 dB, both obtained at 09.00 o’clock. At 11.00 o’clock, the highest noise level is 95.0 dB and the lowest is 89.1 dB. At 13.00 o’clock, the highest noise level is 95.1 dB and the lowest is 90.5 dB. At 15.00 o’clock, the highest noise level is 95.0 dB and the lowest is 90.8 dB. On average, the noise level in grinding station reaches its highest at 92.1 dB and its lowest at 92.8 dB.

| Table 1. Recapitulation of equivalent noise level at all points of measurement |
|-------------------------------------------------|-----------------|-----------------|-----------------|-----------------|
| Point of measurement | 09.00 | 11.00 | 13.00 | 15.00 |
| 1                  | 92.9  | 93.0  | 92.9  | 92.9  |
| 2                  | 94.8  | 95.0  | 95.1  | 95.0  |
| 3                  | 93.1  | 92.1  | 93.1  | 93.6  |
| 4                  | 95.3  | 94.7  | 94.9  | 94.6  |
| 5                  | 95.4  | 92.1  | 93.3  | 93.9  |
| 6                  | 90.8  | 90.7  | 91.0  | 91.2  |
| 7                  | 92.6  | 92.4  | 92.6  | 92.7  |
| 8                  | 88.3  | 89.1  | 91.0  | 91.1  |
| 9                  | 87.5  | 90.5  | 90.5  | 90.8  |

Noise level has exceeded upper safe limit recommended by Occupational Safety and Health (OSHA), i.e. Daily Noise Dose (DND) of 360%–800% [13]. Figure 2 shows that the noise level at the 1st until the 9th point of measurement is far above the NAB allowed by Indonesian Government of Human Resource and Transmigration Decree No 13 The Year 2011 about 85 dB for 8 hours of work per day [14].
Noise distribution pattern on production floor is mapped using noise mapping method using surfer v.11.0 software as shown in figure 3.

Figure 3 shows that all areas on production floor produces noise level higher than the upper safe limit allowed. It can also be seen that all grinding station areas are not safe for operators. The 5th point of measurement has noise level of higher than 94 dB and this is caused by the point is in the mid part and between the grinding machine and the conveyor. However, there is no operator around this point, all the operators are behind the grinding machine and the conveyor. Operators located at the 1st, 3rd, 4th, and 6th measured point are exposed to noise level of 92.5 to 93 dB, while operators at the 7th and 9th are exposed to noise level of 90.5 dB to 91 dB. Sound intensity obtained from every measured point is used to calculate sound source energy. The highest sound source intensity is located at the 2nd and the 5th measured point and the corresponding sound source energy are 0.21 and 0.51 Watt respectively. The maximum allowed exposure allowed for all 9 measured points are all below 8 hours.
### Table 2. Calculation recapitulation of daily noise dose

| Point of measurement | Noise level in the afternoon (dB) | Maximum duration of exposure (min) | DND (%) | Explanation |
|----------------------|----------------------------------|-----------------------------------|---------|-------------|
| 1                    | 92.9                             | 90.58                             | 530     | Unsafe      |
| 2                    | 95.0                             | 71.79                             | 669     | Unsafe      |
| 3                    | 92.9                             | 91.35                             | 525     | Unsafe      |
| 4                    | 94.9                             | 72.48                             | 662     | Unsafe      |
| 5                    | 93.9                             | 81.07                             | 592     | Unsafe      |
| 6                    | 90.9                             | 122.05                            | 393     | Unsafe      |
| 7                    | 92.6                             | 94.23                             | 509     | Unsafe      |
| 8                    | 90.0                             | 143.54                            | 334     | Unsafe      |
| 9                    | 90.1                             | 142.37                            | 337     | Unsafe      |
| **Average**          | **92.6**                         | **100.82**                        | **506** | Unsafe      |

The operators in the grinding station may only be at that place for 1 hour 12 minutes to 2 hours 23 minutes. In reality, however, all the workers work in the station for 8 hours per day. Indonesian Government of Human Resource and Transmigration Decree No 13 The Year 2011 recommends that the allowed upper limit for noise exposure is 85 dB for the duration of 8 hours of work per day. The percentage of Daily Noise Dose (DND) at all points is higher than the normal Daily Noise Dose and therefore is unsafe. NIOSH states that it is still safe for workers exposed to noise on floor production if the DND does not exceed 100%. In reality, as shown in table 2, DND of the workers are of 334-669%, which means all measured points show unsafe value of DND. DND reaches 669% at the 2nd measured point and the smallest DND, 334%, is still in unsafe category.

Noise level can be managed through engineering control approach, for example changing the processing method, using less noisy machines, changing the materials, and closing the noise source. Changing the processing method also means changing how the machine works, which will meet many difficulties in the application. Using less noisy machines means new machines supplies are needed, which also requires large amount of investation. Aside from that, consideration about the durability and quality of the products also becomes important if the material used is to be changed. Closing the source of the noise, however, cannot also be done because operators are working right in front of the machines. These considerations make engineering control application for production process characteristic cannot be taken. It requires further study to apply this approach. Noise level management through administrative control will give special treatment to operators, so that the noise exposure duration can be reduced. This approach can be taken to operators exposed to noise above the upper limit in the grinding station with work hour management. This approach still considers the condition of operators. Operators exposed to noise above the allowed limit will move to other station, so that the exposure received still meets the regulation. Operators work duration is regulated based on noise level at the corresponding work area. After working for the allowed duration, operators will be move to other work station that has lower noise level exposure.

Operators at the grinding station will move to boiler station, power house, purification station, and cooking station. The work duration is the same as the maximum exposure duration allowed. Operators at the 1st point will move after working for 90.58 minutes, operators at the 2nd point will move after working for 71.79 minutes, operators at the 3rd point will move after working for 91.35 minutes, and so forth. Administrative control application at grinding station requires operators’ readiness to work at other work stations. In other words, operators have to understand what work needs to be performed at each production station.
4. Conclusion
The purpose of this article is to observe noise exposure in grinding station by measuring sound pressure level. Noise exposure reaches 97.0 dB, making operators unable to hear instruction clearly, which makes information received prone to error and people need to talk at loud volume. The percentage of Daily Noise Dose (DND) at all measured points are above the normal level, which is unsafe for people. NIOSH states that the safe DND limit for operators are no bigger than 100, while in reality the DND of operators is in the range of 334-669\%, which makes all measured point not safe. Noise level management can be done using administrative control method. Operators already exposed to noise for the maximum duration will be moved to other less noisy station.

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