



Received: 02 July 2019
Accepted: 08 September 2019
First Published: 11 September 2019

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CIVIL & ENVIRONMENTAL ENGINEERING | RESEARCH ARTICLE

Noise level analysis to reduce noise exposure at PT. IT

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Abstract: PT. IT is a textile company that produces grey cloth and printing batik. The production process of making grey cloth and printing batik uses a machine that has the potential to cause noise. The noise level that occurs in one production area reaches 100 dB. This value exceeds the threshold value required by the Republic of Indonesia Minister of Health Regulation No 70 of 2016. Therefore, it is necessary to do research to reduce noise levels in the production area. The noise level measurement and calculation procedure refer to SNI 7231-2009 and KEP-48/MENLH/11/1996. The calculation of the maximum time of exposure to noise workers refers to NIOSH. Noise impact questionnaires are processed with descriptive statistics. The calculation of Noise Reduction Rating (NRR) refers to the Regulation of the Minister of Health of the Republic of Indonesia No 70 in 2016. From the 16 measurement points in the weaving department, 11 points with noise levels above NAB are obtained. The impact of noise perceived by workers includes communication disruption, physiological disorders, and psychological disorders. In order to overcome these problems, it was proposed noise control by using Ear Protector in the form of earmuff with NRR 48 dB.

Subjects: Industrial Engineering & Manufacturing; Production Engineering; Public Health Policy and Practice

Keywords: noise; NAB; NRR; weaving



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PUBLIC INTEREST STATEMENT

The textile industry is a industry with a high noise level. Noise due to the character of the textile industry production machinery has a high noise level plus the placement of many machines in one room resulted in an increase in cumulative noise levels. The highest noise level weaving department of PT. IT of 105.03 dB, the lowest noise level of 87.53 dB. This noise level exceeds the required NAB. The impact of noise felt by workers includes communication disorders, physiological disorders, and psychological disorders. Noise control in the weaving department by using noise hierarchy control which includes: elimination, substitution, engineering control and administrative control and the use of personal protective equipment (PPE). Noise control by elimination, substitution, and engineering control cannot be applied. PPE by wearing ear protectors Noise control in the weaving department is done using ear protectors in the form of earmuffs with NRR 48 dB.

1. Introduction

Noise is all the unwanted sounds originating from the tools of the production process and/or work tools which at a certain level can cause hearing loss (Indonesia Ministry of Manpower Regulation Number 5 of 2018). Noise caused by production process activities is often found in the textile industry. Several studies have shown that the noise level generated by the textile industry is more than 90 dB (Abbasi et al., 2011; Praveen et al., 2014; Nassiri et al., 2016). This high noise is caused by the character of the production machine in the textile industry has a high noise level coupled with the placement of many machines in one room resulting in an increase in cumulative noise levels (Jayawardana et al., 2014).¹

High noise levels have a negative impact on employees in the textile industry. Employees in the textile industry are very valuable assets and an important element in the production process. Therefore, employees must be maintained, fostered and developed to increase their productivity. One of them is by reducing the time of exposure to the noise level received by textile industry employees. Hidayah (2011) states that noise in the workplace of the weaving department affects fatigue in the workforce. High levels of noise in the workplace will cause a decrease in worker concentration and a decrease in worker performance (Fanny, 2015; Nassiri et al., 2013; Sarode, 2014). Noise in the workplace can cause operator work stress (Failasufa et al., 2014; Suciati, 2013). In addition to work stress and labor fatigue, the noise of the work environment of the weaving department also has an impact on the emotional disturbances and cardiovascular burden of the operator (Prabawati, 2016).

The existence of the textile industry in Central of Java Province has a significant role in the economy of this region. The textile industry contributes quite significantly in terms of absorption of the number of workers and the value of exports (Suhardi & Kuncoro, 2013). PT. IT is one of the textile industries in Central Java Province. Products produced by PT. IT is in the form of grey cloth and printing batik. The production department of PT. IT is divided into two, namely the weaving department and the printing department. The weaving department produces grey cloth while the printing department produces printing batik. The number of workers at PT. IT is 1,000 people. Working hours at PT. IT is divided into three shifts these are shift 1, shift 2, and shift 3. Workers who work in shift 1 starts working from 07.00 to 15.00 Western Indonesian Time (WIB), shift 2 starts from 15.00 to 23.00 WIB, and shift 3 starts from 23.00 to 07.00 WIB. The division of work shifts applies to production employees.

Problems that occur at PT.IT is the condition of the work environment that does not support workers in carrying out production process activities. The working environment condition, in this case, is the noise level that exceeds the threshold value. Based on the results of initial measurements in the weaving department, the noise level is known as 100 dB. While the noise level in the printing department is 78 dB. The noise level in the weaving department is above the predetermined threshold value based on the Permenkes No. 70 of 2016 at 85 dB with a maximum time of exposure which is 8 hour. The noise level of the printing department is below the specified threshold value or can be said still within safe limits. High noise levels in the weaving department will have a negative impact on workers in this department. The management of PT. IT must improve the noise conditions in the weaving department.

The objectives of this study are as follows: 1) to find out the noise level in all machine areas in the weaving department, 2) to find out the maximum time of exposure to noise workers, 3) to find out the noise impacts felt by workers in the weaving department, 4) to provide noise control proposals in the weaving department.

2. Research method

This research was carried out through the following stages:

2.1. Data collection

The data that was used in this study consist of primary data and secondary data. Primary data were in the form of noise data at measurement points in the weaving department and noise impact data felt by weaving department workers. Secondary data collected include general data

on weaving section workers, weaving department layouts, types, and specifications of production machines, and employee work times in the weaving department.

The equipment used to measure noise includes 4 in 1 multi-function environment meter, stopwatch to determine measurement time, and GPS application to determine measurement points. The questionnaire was used to collect data about the noise impacts felt by the production department operators of the weaving department. The questionnaire used refers to Rahmi (2009). The questionnaire was given to 40 workers in the weaving department.

2.2. Noise measurement procedure

The noise measurement procedure is based on SNI 7231-2009. The timing of noise level measurement and noise level calculation refers to the KEP-48/MENLH/11/1996.

2.3. Measurement of noise level

The noise level measurement was carried out for 24 h by dividing the measurement time during the day which is 16 h and at night which is 8 h. The measurement period for daytime was done between 06.00 and 22.00 WIB. The time range for night measurements was done between 22.00 and 06.00 WIB. Noise level measurements were carried out every 5 second for 10 minute with the height of a 4 in 1 multi-function measuring meter from the 1.5-meter floor.

When measuring the noise level in the weaving department of PT. IT, it was divided into seven that is:

- the measurement of the noise level at 06.00 WIB represents the time range of 06.00–09.00 WIB.
- the measurement of the noise level at 09.00 WIB represents the time range of 09.00–14.00 WIB
- the measurement of the noise level at 14.00 WIB represents the time range of 14.00–17.00 WIB
- the measurement of the noise level at 17.00 WIB represents the time range of 17.00–22.00 WIB
- the measurement of the noise level at 22.00 WIB represents the time range of 22.00–24.00 WIB
- the measurement of the noise level at 24.00 WIB represents the time range of 24.00–03.00 WIB
- the measurement of the noise level at 03.00 WIB represents the time range of 03.00–06.00 WIB

Weaving department noise measurement points are 16 points including Picanol Loom machine area, RRT Loom machine area, Toyoda Loom machine area, Palettan area, Pencucukan area, Control room, Sizing area, Warping area, Operator room, and Workshop room. The determination of measurement points is shown in Table 1.

Table 1. The measurement point of the weaving department

Measurement Point	Area	Measurement Point	Area
1	Picanol loom machine	9	Workshop room
2	Picanol loom machine	10	Control room
3	RRT loom machine	11	Toyoda loom machine
4	RRT loom machine	12	Palletizing
5	Toyoda loom machine	13	Reaching
6	Toyoda loom machine	14	Sizing
7	Toyoda 2 loom machine	15	Warping
8	Operator room	16	Warping

2.4. Calculation of equivalent continuous sound pressure level (Leq), daytime noise level (Ls), night noise level (Lm), and daytime and night noise level (Lsm)

The formula used to calculate Leq, Ls, Lm, and Lsm refers to the KEP-48/MENLH/11/1996 as follows:

$$\text{Leq} = 10 \cdot \text{Log} \left[\frac{1}{n} \sum T_n 10^{0.1 L_n} \right] \text{ dB} \quad (2.1)$$

$$\text{Ls} = 10 \cdot \text{Log} \frac{1}{16} \left[\left(T_1 \times 10^{0.1 L_1} \right) + \left(T_4 \times 10^{0.1 L_4} \right) \right] \text{ dB} \quad (2.2)$$

$$\text{Ls} = 10 \cdot \text{Log} \frac{1}{8} \left[\left(T_5 \times 10^{0.1 L_5} \right) + \left(T_7 \times 10^{0.1 L_7} \right) \right] \text{ dB} \quad (2.3)$$

$$\text{Lsm} = 10 \cdot \text{Log} \frac{1}{24} \left[\left(16 \times 10^{0.1 L_5} + 8 \times 10^{0.1(L_m + 5)} \right) \right] \text{ dB} \quad (2.4)$$

Information:

Leq	=	The equivalent continuous sound pressure level within 10 minutes
n	=	The amount of noise level measurement data every 5 seconds for 10 minutes
Tn	=	Frequency noise level data at each noise interval
Ln	=	Average noise level at each noise interval
Ls	=	Daytime noise level
T1	=	Noise level measurement time intervals during the period of 06.00–09.00 WIB
T2	=	Noise level measurement time intervals during the period of 09.00–14.00 WIB
T3	=	Noise level measurement time intervals during the period of 14.00–17.00 WIB
T4	=	Noise level measurement time intervals during the period of 17.00–22.00 WIB
L1	=	Leq calculation results in the period of noise level measurement at 06.00 WIB
L2	=	Leq calculation results in the period of noise level measurement at 09.00 WIB
L3	=	Leq calculation results in the period of noise level measurement at 14.00 WIB
L4	=	Leq calculation results in the period of noise level measurement at 17.00 WIB
Lm	=	Night noise level
T5	=	Noise level measurement time intervals during the period of 22.00–24.00 WIB
T6	=	Noise level measurement time intervals during the period of 24.00–03.00 WIB
T7	=	Noise level measurement time intervals during the period of 03.00–06.00 WIB
L5	=	Leq calculation results in the period of noise level measurement at 22.00 WIB
L6	=	Leq calculation results in the period of noise level measurement at 24.00 WIB
L7	=	Leq calculation results in the period of noise level measurement at 03.00 WIB
Lsm	=	Daytime and night noise level

2.5. Comparison of the Lsm value with the noise threshold value

The results of the Lsm calculation are then compared with noise threshold values for industrial areas based on the Permenkes No. 70 of 2016. The allowable threshold value is 85 dB with a maximum exposure time that is 8 hour.

2.6. Calculating the maximum time for noise-exposed worker

The formula used to calculate the maximum time for noise-exposed workers refers to the National Institute of Occupational Safety and Health (NIOSH) as follows:

$$T = \frac{480}{2^{(L-85)/3}} \tag{2.5}$$

Information:

- T = The maximum time of workers may face (contact) with the noise level (in minutes) is known as the maximum of the time exposure (NIOSH formula)
- 480 = 8 working hours/day. 1 hour = 60 minutes
- L = Noise level (intensity (dB))
- 85 = Exchange rate
- 3 = Intensity trade-off, that is a number that shows the relationship between the intensity of noise and noise.

2.7. Processing of questionnaires to determine the noise impact felt by workers

Questionnaires filled out by respondents are then processed using descriptive statistical methods.

2.8. Control of noise

Control of noise in this study was carried out by using the Ear Protector (APT). The stages in choosing ear protector were done by calculating the Noise Reduction Rating (NRR) by using the following equation:

NRR for single protection:

$$\text{Effective exposure} = \text{dBA}_{\text{exposure}} - [\text{NRR}_{\text{APT}} - 7 \text{ (correction factor)}] \times 50\% \tag{2.6}$$

NRR for multiple protection. The multiple protection means using two ear protections (APT) namely earplug and earmuff.

$$\text{Effective exposure} = \text{dBA}_{\text{exposure}} - [\text{NRR}_{\text{the highest APT}} - 7 \text{ (correction factor)}] \times 50\% \tag{2.7}$$

3. Result and discussion

3.1. Data from results of noise measurement

Noise measurement is carried out every 5 s for 10 min. Data from the noise collected for 10 min were 120. Data from noise measurement at point 1 are shown in Table 2.

From the table, it can be concluded to indicate that the noise levels with a maximum of 104.9 dB, to a minimum of 94.7 dB at point 1. The measurements of noise levels result are then processed into a table of noise levels frequency distribution of point 1 shown in Table 3.

97.1	97.9	99.2	97.2	102.8	97.1	98.3	99.3	97.2	102.9
97.2	98.3	97.2	94.7	103.0	97.2	98.5	97.3	99.4	103.0
100	99.4	98.6	99.5	103.1	100	98.8	98.5	103.8	103.2
100.1	98.8	97.8	103.9	103.2	102	104.9	100.3	103.9	103.3
99.6	98.9	100.3	103.9	103.4	98.1	99.7	100.6	103.9	103.4
100.1	99.9	100.7	104	103.7	100.6	100	100.8	104	103.7
100.7	100	101.1	104	103.7	97.2	101.8	101.7	104	102.6
98.9	101.9	101.7	104	102.5	98.5	102	98.6	104.2	102.5
97.8	98.6	99.4	104.2	102	97.7	98.7	101.8	104.3	102.4
97.7	98.7	104.9	104.3	102.1	97.9	98.7	97.8	104.3	102.1
97.5	99	97.6	104.3	104.7	98.4	99.1	97.5	104.3	104.9
104.7	99.2	104.7	104.4	103.6	97.9	99.2	104.5	103.8	103.6

Table 3. Noise levels frequency distribution of point 1 at 06:00 WIB

No	Noise interval	Average	Frequency
1	94.7-96.0	95.4	1
2	96.1-97.4	96.8	9
3	97.5-98.8	98.2	26
4	98.9-100.2	99.6	21
5	100.3-101.6	101.0	8
6	101.7-103.0	102.4	18
7	103.1-104.0	103.6	22
8	104.1-105.8	105.2	15

3.2. The Leq, Ls, Lm, and Lsm value calculation

The next stage is to calculate the value of Leq, Ls, Lm, and Lsm for all measurement points in the weaving department. The following is the Leq value calculation of measurement point 1 at 06.00 WIB using Equation (2.1).

$$\begin{aligned} \text{Leq} &= 10 \cdot \text{Log} \left[\frac{1}{n} \sum T_n 10^{0.1 L_n} \right] \text{dB} = 10 \text{Log} [1/120 \times ((1 \times 10^{0.1 \times 95.4}) + (9 \times 10^{0.1 \times 96.8}) \\ &+ (26 \times 10^{0.1 \times 98.2}) + (21 \times 10^{0.1 \times 99.6}) + (8 \times 10^{0.1 \times 101.0}) + (18 \times 10^{0.1 \times 102.4}) \\ &+ (22 \times 10^{0.1 \times 103.6}) + (15 \times 10^{0.1 \times 105.2}))] = 100,9 \text{dB} \end{aligned}$$

By using Equation (2.1), the Leq value of point 1 is at 09:00 WIB, 14:00 WIB, 17:00 WIB, 22:00 WIB, 24:00 WIB, and 03:00 WIB can be figure out. The results of the Leq value calculation of point 1 are fully described in Table 4.

The results of the Leq value calculation of point 1 during the time measurement are the basis in calculating the Ls, Lm, and Lsm value of the measurement point 1. The Ls value calculation refers to Equation (2.2), to the Lm value of 2.3, to the Lsm value calculation of 2.4. The following is the Ls, Lm, and Lsm value calculation of the measurement point 1.

$$\begin{aligned} \text{Ls} &= 10 \cdot \text{Log} \frac{1}{6} [(T1 \times 10^{0.1L1}) + \dots + (T4 \times 10^{0.1L4})] \text{dB} \\ &= 10 \cdot \text{Log} \frac{1}{16} (3 \times 10^{(0.1 \times 100.90)}) + (5 \times 10^{(0.1 \times 101.72)}) + (3 \times 10^{(0.1 \times 100.24)}) + (5 \times 10^{(0.1 \times 98.87)}) \\ &= 100.54 \text{dB} \end{aligned}$$

$$\begin{aligned} \text{Lm} &= 10 \cdot \text{Log} \frac{1}{8} [(T5 \times 10^{0.1L5}) + \dots + (T7 \times 10^{0.1L7})] \text{dB} \\ &= 10 \cdot \text{Log} \frac{1}{8} (2 \times 10^{0.1 \times 99.01}) + (3 \times 10^{0.1 \times 101.26}) + (3 \times 10^{0.1 \times 98.71}) = 99.90 \text{dB} \end{aligned}$$

Table 4. Leq value calculation of point 1 at all time measurement

Time Measurement (in hour)	Leq value (dB)
06:00 WIB	100.90
09:00 WIB	101.72
14:00 WIB	100.24
17:00 WIB	98.87
22:00 WIB	99.01
24:00 WIB	101.26
03:00 WIB	98.71

$$\begin{aligned}L_{sm} &= 10 \cdot \text{Log} \frac{1}{24} \left[\left(16 \times 10^{0.1L_s} + 8 \times 10^{0.1(L_m+5)} \right) \right] \text{ dB} \\ &= 10 \cdot \text{Log} \frac{1}{24} \left[\left(16 \times 10^{0.1 \times 100.54} + 8 \times 10^{0.1(99.90+5)} \right) \right] \text{ dB} = 102.50 \text{ dB}\end{aligned}$$

Based on the L_{sm} value calculation obtained the average value of one point noise for 24 h (L_{sm}) is equal to 102.50 dB. By using Equations 2.2 and 2.3, and 2.4 obtained the values of L_s , L_m , and L_{sm} for the 16 noise measurement points shown in Table 5. The L_{sm} value then will be compared with the threshold value (NAB) based on the Indonesia Ministry of Health Regulation No 70 years 2016.

The result of L_{sm} value calculation from the 16 measurement points has 11 measurement points with the value of the L_{sm} exceeding the required NAB with the highest L_{sm} value at the 11th measurement point (machine area Toyoda Loom) of 105.03 dB, to the lowest at the 15th measurement point (machine area warping 1) of 84.50 dB. There are five measurement points with values below the NAB, even though it is also close to NAB. This indicates that the noise levels in the weaving department have been dangerous for workers.

The difference in noise intensity between one point and another point is caused by several factors including the noise source strength and its distance from the noise source. The farther away, sound waves that propagate through the air will experience a decrease in intensity due to friction with the air. In addition to both the impact of sources and distances, there is a barrier in the form of a wall surrounding the noise source which will certainly reflect the sound coming out of the production machines.

3.3. The time of exposure to noise calculation at all measurement points

The next stage is to calculate the time of exposure to noise allowed by NIOSH using an Equation of (2.5). The following is an example of the time of exposure to noise calculation with a maximum of point 1.

$$T = \frac{480}{2^{(102.50-85)/3}} = 8.42 \text{ minutes}$$

The time of exposure of workers to noise at point 1 with a noise level of 102.5 dB is 8.42 min or 0.14 h. The results of the length of time of exposure of workers calculation for all measurement points are shown in Table 6.

Based on the length of time of exposure to noise is perceived by workers after it has been calculated using an equation of 2.5, obtained 11 measurement points that exceed the NIOSH standard which is 8 h of exposure for noise levels of 85 dB. The longest time of exposure to noise at point 15 (machine area warping 1) with the time of exposure of 538.78 min or 8.98 h. The shortest time of exposure to noise at point 11 (toyoda loom machine) with the time of exposure of 4.69 min or 0.08 h. The higher the noise level, the shorter the time of exposure. The lower the noise level, the longer the time of exposure. Workers are allowed to be perceived as noise to a specified time limit. In this regard, further handling of 11 measurement points with a noise level that exceeds the noise quality standard is necessary in order to avoid work-related illnesses for workers mainly caused by high noise levels.

3.4. Noise impacts felt by weaving department workers

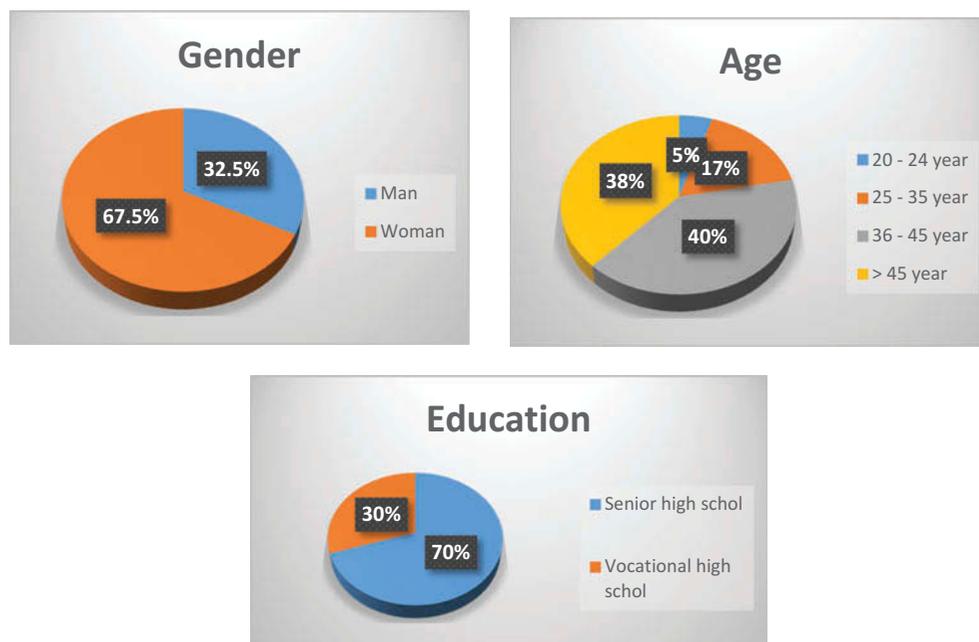
The next stage of the study is to identify the noise impacts felt by weaving department workers. The results of processing questionnaires filled in by weaving department workers are divided into two, namely questionnaires related to the identity of respondents and questionnaires related to the noise impact. The respondents from the weaving department were 40 people. The results of processing the questionnaire related to the identity of the respondents are shown in Figure 1.

Table 5. The value of Ls, Lm, and Lsm of weaving department at PT. IT

Measurement point	Area	Ls (dB)	Lm (dB)	Lsm (dB)	NAB (dB)	Information
1	Picanol loom machine	100.54	99.90	102.50	85	Above NAB
2	Picanol loom machine	100.28	99.29	99.51	85	Above NAB
3	RRT loom machine	100.25	98.36	102.08	85	Above NAB
4	RRT loom machine	101.68	99.55	102.85	85	Above NAB
5	Toyoda loom machine	101.56	99.96	103.00	85	Above NAB
6	Toyoda loom machine	100.57	99.35	102.22	85	Above NAB
7	Toyoda 2 loom machine	100.42	100.27	102.68	85	Above NAB
8	Operator room	84.66	85.54	87.53	85	Above NAB
9	Workshop room	86.53	86.69	88.98	85	Above NAB
10	Control room	83.07	82.01	84.80	85	Below NAB
11	Toyoda loom machine	100.68	103.59	105.03	85	Below NAB
12	Palletizing	82.47	83.01	84.89	85	Below NAB
13	Reaching	82.06	82.56	84.73	85	Below NAB
14	Sizing	82.90	82.00	84.72	85	Below NAB
15	Warping	81.09	82.70	84.50	85	Below NAB
16	Warping	85.22	85.32	87.63	85	Above NAB

Table 6. The length of time of exposure to the 16 measurement points			
Measurement Point	The length of time of exposure (in minutes)	The length of time of exposure (in hour)	Information
1	8.42	0.14	Above NIOSH
2	16.79	0.28	Above NIOSH
3	9.27	0.15	Above NIOSH
4	7.76	0.13	Above NIOSH
5	7.50	0.12	Above NIOSH
6	8.98	0.15	Above NIOSH
7	8.07	0.13	Above NIOSH
8	267.53	4.46	Above NIOSH
9	191.37	3.19	Above NIOSH
10	502.70	8.38	Below NIOSH
11	4.69	0.08	Above NIOSH
12	492.36	8.21	Below NIOSH
13	510.90	8.51	Below NIOSH
14	512.08	8.53	Below NIOSH
15	538.78	8.98	Below NIOSH
16	261.42	4.36	Above NIOSH

Figure 1. The identity of the respondent.



The respondents in this study were mostly female with a percentage of 67.5%. The age of respondents is mostly in the range of 36–45 years with a percentage of 40%, to more than 45 years with a percentage of 38%. Respondents education was divided into two, namely senior high school (70%) and vocational high school (30%).

The results of the processing of noise impact questionnaires felt by respondents were shown in Figures 2–4. The figure showed that respondents experienced communication disruption of 92.5% (Figure 2).

Figure 2. Communication disruption.

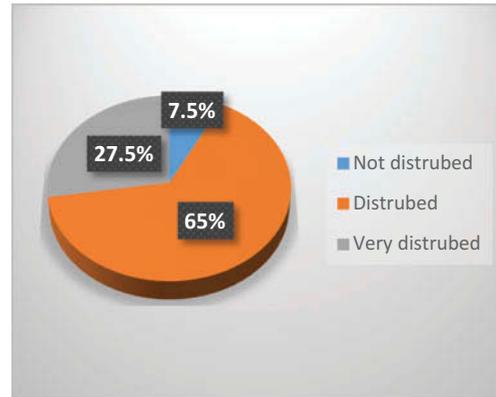


Figure 3. Physiological disorders.

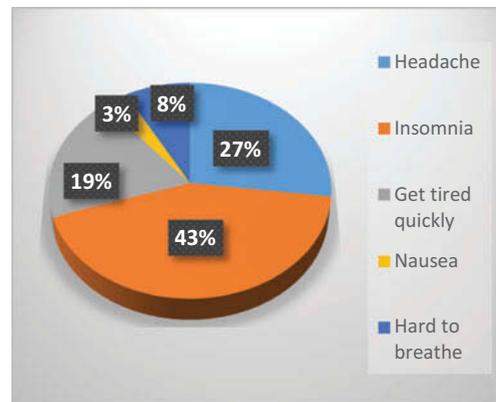
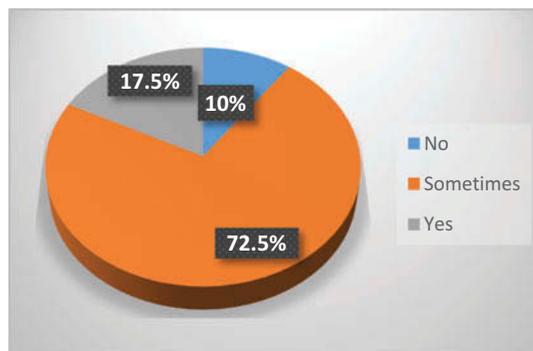


Figure 4. Psychological disorders.



The communication disruption level is disturbed by 65%, to a very disturbed of 27.5%. Communication disruption experienced by respondents in the form of difficulties to understand the words of his co-workers, communication between co-workers by shouting, and reprimand from co-workers due to lack of understanding what was discussed by his co-workers. If they were left unchecked, it could cause an error in the production process activities. The results of this study reinforce previous studies conducted by Kholik and Krishna (2012); Buksh et al., (2018) as well.

Physiological disorders perceived by respondents are shown in Figure 3. Physiological disorders included headache of 27%, insomnia of 43%, get tired quickly of 19%, nausea of 3%, and hard to breathe of 8%. The results of this study reinforce the previous study conducted by Mokhtar et al., (2007), Kholik and Krishna (2012), Ibrahim et al., (2014), Buksh et al. (2018) as well.

Psychological disorders due to high noise levels were perceived by most respondents (Figure 4). As many as 17.5% complained of having psychological disorders, to 72.5% of respondents stated that they sometimes experienced psychological disorders. Psychological disorders experienced by respondents in the form of feeling uncomfortable when in the workplace and feeling more easily emotion due to high noise workplaces. The results of this study reinforce previous studies conducted by Kholik and Krishna (2012), Ibrahim et al. (2014) as well.

When the weaving department workers are continuously in the noise workplace, they intend to move to work. This is approved by data said that 77.5% of respondents from the weaving department want to change workplaces with lower noise levels (Figure 5).

The management of PT. IT has better to carry out the control of noise in the weaving department considering the workers feel uncomfortable with their high noise workplaces. If they were left unchecked, it could cause a decrease in the work productivity of the weaving department workers.

3.5. Noise control of the weaving department

Based on the calculation of the time of exposure to noise at all 16 measurement points, it turns out that there were 11 measurement points that were above the NIOSH standard as described in Table 6. The noise level is at the 11 measurement points with a maximum of 105.03 dB (point 11), to a minimum of 87.53 dB (point 8). This conducted to indicate that improvements need to be made to reduce the noise level.

Based on the result of Lsm calculation, 11 measurement points exceeded the threshold value (Table 5). The measurement points that exceed the threshold value consist of eight measurement points related to the weaving process and three measurement points as support of the weaving process. Measurement points that exceed the threshold value are shown in Table 7.

Noise control carried out in this study is using the Noise Hierarchy Controls Approach. The hierarchy stage includes elimination, substitution, engineering controls and the use of personal protective equipment (PPE). Noise control is focused on the activities of weaving process.

3.5.1. Elimination

Elimination on the noise sources can be done by closing or eliminating the process which become the source of the noise. The main process on the weaving department is weaving. The source of the noise in the weaving department comes from the loom machine. Workers in the weaving department are on duty to oversee the weaving process and connect the yarn if there is a broken yarn. Workers have to stand by near the loom machine with a high risk of noise exposure. The elimination of weaving process can not be done because the merging between weft threads and warp thread is done in the weaving process. Because the elimination can not be done, then the next level of noise control is the substitution stage.

Figure 5. Workers who want to move to work.

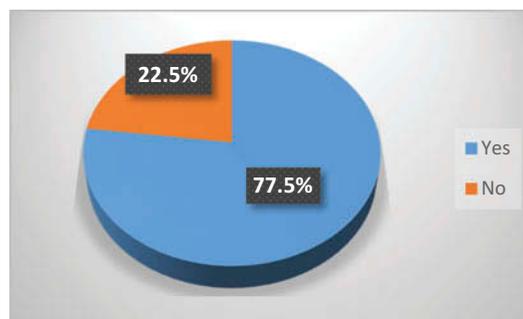


Table 7. The measurement points and production process			
Measurement point	Area	Production process	Noise levels (dB)
1	Picanol loom machine	Weaving	102.50
2	Picanol loom machine	Weaving	99.51
3	RRT loom machine	Weaving	102.08
4	RRT loom machine	Weaving	102.85
5	Toyoda loom machine	Weaving	103.00
6	Toyoda loom machine	Weaving	102.22
7	Toyoda 2 loom machine	Weaving	102.68
8	Operator room	Briefing	87.53
9	Workshop room	Repairing	88.98
11	Toyoda loom machine	Weaving	105.03
16	Warping	Warping	87.63

3.5.2. Substitution

Substitution is a replacement of process or noise source with another process or device that has a lower noise level but still allows the access of operation and maintenance. The process of substitution in the weaving process can not be done because the weaving process is the main process of woven fabrics production in the weaving department.

The source of the noise in the PT. IT weaving department comes from the looms machines with an old technology. Old loom machines produce high level of noise. While loom machines with new technology produce low level of noise. Based on interviews with the management of PT. IT, the cost of replacing the old loom machine with a new loom machine is Rp 15,12 billion. With that cost, PT. IT can not afford to buy new loom machines as the replacement of old loom machines. So that, the substitution of old loom machine can not be done. Next level of noise control is engineering control.

3.5.3. Engineering control

Engineering control is one of the efforts that has a significant impact on reducing noise levels. One of the ways that can be done is adding a barrier or enclosure. Barrier is an instrument designed by using dampening material to minimize the noise level that is generated and received by the operators (Figure 6). While the enclosure is an instrument used to cover the machine so the noise from the machine does not come out and pollute the environment (Figure 7).

Engineering controls by adding barriers and enclosures can not be done because it can deter the workers to the machines. Weaving activities are a work done by direct interaction between

Figure 6. Barrier concept on the machine.

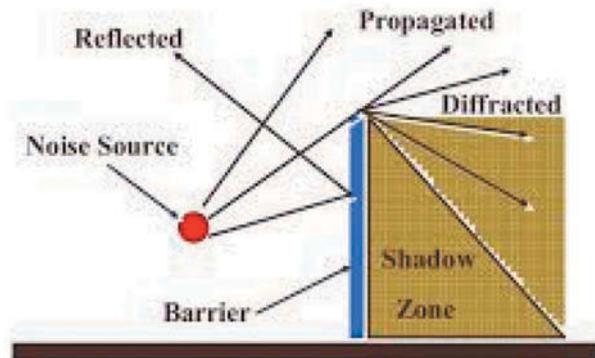


Figure 7. Enclosure concept on the machine.



workers and machines. Loom machines at PT. IT is a manual type loom machines that can not be left for a certain time interval (Figure 8). This makes workers have to be close to the machine.

3.5.4. Personal protective equipment (PPE)

The next stage of noise control in the weaving department is to use PPE. PPE is provided in the form of ear protection to workers in the area of workplaces. There are two types of ear protectors to protect from the noise workplaces, namely earplugs and earmuffs. Every ear protector has the ability to reduce noise. The effectiveness and ability of ear protectors in reducing noise can be seen based on NRR values. Earplug can reduce noise by 30 dB while earmuff can reduce noise between 40 and 50 dB (Pulat, 1992).

Figure 8. Operators when operating the loom machines.



Table 8. Effective exposure

Measurement point	Noise levels (dB)	Effective exposure (dB _{effective})
1	102.50	82
2	99.51	79.01
3	102.08	81.58
4	102.85	82.35
5	103.00	82.50
6	102.22	81.72
7	102.68	82.18
11	105.03	84.53

The proposed ear protector (APT) is an earmuff with NRR of 48 dB. The following is an example of NRR calculation for single protection at measurement point 1 using an equation of 2.6.

$$\begin{aligned} \text{Effective exposure} &= \text{dB}_{\text{exposure}} - [\text{NRR}_{\text{APT}} - 7(\text{correction factor})] \times 50\% = 102.50 - [48 - 7] \times 50\% \\ &= 82\text{dB} \rightarrow \text{exposure is below NAB} \end{aligned}$$

The results of effective exposure calculation for the nine measurement points are shown in Table 8.

The results showed that using earmuff with an NRR of 48 dB can reduce effective exposure perceived by the weaving department workers. Effective exposure is below the required NAB. Decreasing the noise level received by workers will prevent workers from the risk of hearing loss. Some research also suggests that the use of ear protection equipment can reduce the risk of hearing loss in production workers (Ibrahim et al., 2016; Ramadhani et al., 2017).

However, compliance with the use of ear protection at work with high noise is still a major problem among workers. The use of ear protection equipment causes workers to experience interference in communicating with co-workers and causes discomfort in the ear (Fitriyani & Wahyuningsih, 2016; Ramadhani et al., 2017).

The management of PT. IT must require workers in the weaving department to wear earmuffs while working in areas with noise intensity above the NAB. The use of ear muff must also be considered by the management by providing information to workers both during the safety talk or safety meeting so that workers understand the usage of earmuff is good and right in order to maximize the function of the use of ear muff.

4. Conclusion

According to Indonesia Ministry of Health Regulation No. 70 of 2016, noise level day to night (the value of L_{sm}) in the weaving department of 16 measurement points conducted to indicate that there are 11 measurement points with results above the required NAB. There are 11 measurement points that exceed the NIOSH standard, which are 8 h of exposure for the 85 dB noise level. The majority of weaving department workers experienced communication disruption (92.5%), physiological disorders (100%) and psychological disorders (90%). Noise control in the weaving department is done using ear protector in the form of ear muff with NRR 48 dB.

Funding

The authors received no direct funding for this research.

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Citation information

Cite this article as: Noise level analysis to reduce noise exposure at PT. IT, Bambang Suhardi, Muhammad Abdu Haq Navi & Rahmadiyah Dwi Astuti, *Cogent Engineering* (2019), 6: 1666629.

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