Effect of Occupational Noise Exposure to Work-Fatigue of Indonesian Crumb Rubber Plants

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Abstract. The purpose of this research was to analyze the effect of noise on the level of work-fatigue in the production area of three crumb rubber plants at Padang City, Indonesia. It also examines the impact of age, period work, marital status, and education level on work-fatigue. Occupational noise in the working area was measured using a Sound Level Meter, while work-fatigue was measured using the Indonesian fatigue measurement questionnaire (KAPUK2). The respondents of this study were workers in these plants, 213 people in the wet-area, and 135 people in the dry-area. Results showed that the average noise of the production area had exceeded the threshold value, which was 90.98 dB. There were 26.19% experienced mild-fatigue, 71.43% moderate-fatigue, and 2.38% heavy-fatigue. Noise, age, and working experience were a related and significant influence on work-fatigue, where the probability value was respectively 0.046, 0.001, and 0.000 (p≤ 0.05). The results of multiple regressions showed that occupational noise was the most influential factor in the occurrence of work-fatigue with an odds ratio of 3.92.

1. Introduction
Noise can be identified as an unwanted voice. This state conveys that noise is voice pollution. In addition, the noise has been ranked second among several environmental triggers for public health impacts [1], including hearing loss. In general, hearing loss is the fourth highest cause of disability, and there are an estimated 466 million people with hearing loss [2]. In developing countries, occupational noise exposure is the second most self-reported occupational disease with functional, social, emotional, and economic impacts on industrial workers [3]. This situation is caused by exposure to sound levels or duration that damage cochlear hair cells, and may have been advanced at that time to cause sufficient disability [4]. It can develop gradually over time with excessive noise exposure resulting from the manufacturing industry [5].

Exposure to excessive work noise can cause hearing loss, which is a partial or complete hearing loss in one or both ears as a result of work [6]. Worldwide, 16% of crippling hearing loss in adults is caused by work noise. Hearing loss caused by noise at work is a common occupational disease. Hearing loss is irreversible and irreversible; however, hearing loss can be prevented by health management in the workplace. In recent years, many studies have emerged in order to avoid people
from being affected by noise. Not only hearing loss, constant exposure to noise also causes health problems such as sleep disorders [7]–[10], cardiovascular effects [11], [12], learning disorders [13], [14]and chemical hypertension of heart disease [15]. "Burden of Disease from Environmental Noise," as the most recent document published by the World Health Organization (2018) [2], has provided evidence-based descriptions of the consequences of environmental noise on health. According to the report, noise is considered as one of the most severe general physical factors that contribute to an increased risk of environmental and occupational health hazards in the workplace.

Nowadays, economic development in most countries leads to extraordinary growth in industrial processes and technological advancements, thus impacting living standards. Most industries make less effort to increase the consequences of their environmental performance as a result of various production activities that produce noise [16]. However, people were faced with attacks of noise pollution as one of the critical problems in their work environment and residence. This technological growth leads to health complications, which include: hearing loss and mental balance [17]–[19]. Research has shown that noise from factories has severe consequences for changes in worker performance and productivity [20], [21] as well as poor communication resulting in increased chances of work accidents [22]. Production quality and volume are essential factors in the production process, which can be hampered by poor environmental conditions such as noise, thus affecting the efficiency of a company [23], [24]. Noise is a universal occupational health problem today, especially in developing countries. This situation is worse in these countries because less effort is spent on noise control [25]. Work hazards have indeed declined in developed countries, due to the introduction of protective measures. Data on developing countries are not available, but the evidence shows that average sound levels are well above the recommended employment threshold in many developed countries [26]. Thus, the average noise level in developing countries will probably increase significantly because noise control and protection are not always carried out in conjunction with industrialization. This is one of the common problems associated with manufacturing that can cause large expenditures and severe health problems [27].

In Indonesia, the noise quality standard for the industrial work environment was 85 dB (A) (8 hours/day), which was regulated based on the Regulation of the Indonesian Health Ministry Number 70 of 2016 concerning Standards and Requirements for Industrial Work Environment Health. When comparing standards with the National Institute for Occupational Safety and Health (NIOSH), then this Indonesian standard was quite stringent. The NIOSH standard sets 85 dB for the allowable time of 16 hours per day as the Recommended Exposure Limit (REL). It makes specific recommendations on key elements of an effective hearing conservation program. Besides, the OSHA standard also determines 15 minutes. Time Weighted Average (TWA) exposure should not be exceeded at any time during the working day, even if the overall eight hours of TWA is below the Threshold Value and the Total Weighted value (TLV-TWA). Workers may not be exposed more than four times per day to concentrations between TLV-TWA and Occupation Exposure Limit (OEL). The NIOSH standard was a more protective limit for health. It was estimated that about one in four workers exposed to 90 dB eight hours per day for 40 years of work would suffer a hearing loss that can be compensated for by noise, compared to only about one in twelve workers who exposed to NIOSH REL 85 dB The highest opening time of 85 decibels was eight hours, while the noise level was 110 dB, the maximum opening time should not exceed one minute and 29 seconds [6].

In terms of application, negligence was still ordinary in Indonesia. Including in the Padang city, the capital of the West Sumatra province. In this city, there were three crumb rubber plants with huge production for the export of Indonesian rubber. The production process carried out by these three companies uses tools that produced loud noises and cause noise. Noise is one of the causes of work-fatigue. Work-fatigue was an individual's total response to psychosocial stress experienced in a certain period, and work-fatigue tends to reduce the achievement or motivation of the worker concerned. Work-fatigue was not only related to physical and psychological fatigue but is more related to the feeling of fatigue, decreased motivation, and decreased work productivity [28]. Subjective work-fatigue is a feeling of fatigue that is felt by workers, besides it results in reduced motivation and can
reduce mental and physical activity to a certain degree. Subjective work-fatigue measurement can use the fatigue measurement questionnaire, namely, in the Indonesian Language is "Kuesioner Alat Ukur Perasaan Kelelahan Kerja" (KAUPK2). This questionnaire method adopts the IFRC and Fatigue Assessment Scale/FAS. The KAUPK2 questionnaire, with 17 questions, aims to find out all unpleasant feelings in workers who experience work-fatigue. The advantage of the KAUPK2 method is simple, valid, reliable, and in Indonesian (suitable for Indonesian workers) [28].

This study aims to analyze the level of noise and the effect of work environment noise on work-fatigue, which occurs in the production area of the three crumb rubber plants located in the city of Padang. During 2019, there were 11 work accidents in the production area of these plants. The cause of these cases was due to employee negligence due to fatigue.

2. Materials and methods

This research was carried out in production areas in three crumb rubber plants in Padang City, West Sumatra, Indonesia, which are along the Padang City by-Pass Road. Research time was conducted in November 2019 to January 2020 (before COVID-19 pandemic in Padang), including the time of field observations, distribution of questionnaire sheets (KAUPK2), sampling, data processing, and analysis.

The observation was carried out by direct observation in the production area by seeing and observing the work carried out in the production process as well as interviews conducted to get a general picture of the data needed in this study. The interview was explicitly for workers who work in the production area. Respondents were all workers and divided into 213 people in wet areas and 135 people in dry areas.

Noise measurements were carried out using a Sound Level Meter (SLM) tool in the production area for eight hours during working hours (08.00 AM - 04.00 PM). Noise measurement in each factory has five sampling points (where workers carry out work activities close to the source of noise), three points in the wet-area, and two points in the dry-area. The wet-area sampling point consists of point 1 (breaker), point 2 (hammermill), and point 3 (creeper). While the sampling point in the dry-area consists of point 4 (cutter) and point 5 (dryer), each location was carried out four times when data collection, namely:

- L1 was taken at 09.00 AM representing the hours of 08.00 - 10:00 AM;
- L2 was taken at 11.00 AM representing 10:00 AM - 12.00 PM;
- L3 was taken at 1.00 PM representing 12.00 - 02.00 PM;
- L4 was taken at 03.00 PM representing hours 02.00 - 04.00 PM.

Furthermore, the points were measured using SLM for 10 minutes, with readings carried out every five seconds to obtain 120 data points, and the results were recorded. The determination of this measurement point refers to Indonesian Standard No 7231 of 2009[29].

Statistical tests to see the effect between variables with work-fatigue, using the Pearson Product Moment correlation method. Testing multiple regression analysis needs to be done to see which variable most influences work to fatigue in the crumb rubber industries

3. Results and discussion

3.1. Noise Measurement Results

The results of noise measurements in production areas (wet and dry areas) at each plant can be seen in the following table 1.
### Table 1. Noise measurement results in production areas.

| Plant       | Noise Measurement (dB) | Mean ± SD  |
|-------------|------------------------|------------|
| Wet-Area    |                        |            |
| I           | 88.1                   |            |
| II          | 90.1                   | 89.9 ± 1.8 |
| III         | 91.7                   |            |
| Dry-Area    |                        |            |
| I           | 94.9                   |            |
| II          | 85.1                   | 90.1 ± 4.9 |
| III         | 90.2                   |            |

Based on table 1 shows that the noise at measurement points in both wet and dry areas in each factory has exceeded the Threshold Value (TLV) based on the Regulation of the Indonesian Health Ministry Number 70 of 2016. The allowable TLV was 85 dB. The average noise in the wet-area is 89.9 dB, while the dry-area is 90.1 dB.

#### 3.2. Characteristics of Respondents

Workers who were respondents of this study were 348 people. Table 2 shows the characteristics of respondents.

### Table 2. Baseline characteristics of respondents.

| Characteristics          | Percentage (%) |
|--------------------------|----------------|
| Age (year)               |                |
| Teenager (<25)           | 10.71          |
| Mature (25-45)           | 65.48          |
| Old (>45)                | 23.81          |
| < 5                      | 19.05          |
| Working Experience (Year)|                |
| 5-10                     | 26.19          |
| > 10                     | 54.76          |
| Marital Status           |                |
| Unmarried                | 11.90          |
| Married                  | 88.10          |
| Education                |                |
| High School              | 26.19          |
| Senior High School       | 73.81          |

Based on table 2, it can be seen that the most age categories are adults with a range of 26 - 45 years (65.48%), wherein that age range workers are in productive age at work. The most considerable frequency of tenure was in the > 10-year group by 54.76%. This data shows that during the work period, workers are more experienced in carrying out their work. The percentage of the frequency of married workers was 88.1%. This number was because workers were in the age range that should already have a family. Furthermore, most of the last education level of workers was high school with 73.81%

#### 3.3. Fatigue Measurement Results using the KAUPK2

Categories on this questionnaire were divided into three, namely mild work-fatigue with a score of 17-45, moderate work-fatigue with a score of 46-74, and heavy work-fatigue with a score of 75 - 102 [28]. The frequency distribution of work-fatigue categories can be seen in figure 1. Based on figure 1, it can be seen that the level of work-fatigue was in the moderate category (71.43%). Workers who experience heavy fatigue category were workers who work in wet-area, especially near creeper and hammermill machines.
3.4. Relationships and Effects of Noise on Work-fatigue

Based on a statistical analysis of correlation and the t-test of noise and work-fatigue produces a probability value (p-value) of 0.046 (p ≤ 0.05) and a t-value of 2.024 > t-table of 1.989. This value shows that noise is significantly related and has an influence on work-fatigue in crumb rubber plants of Padang.

In addition to hearing loss, noise exposure can cause non-hearing effects, such as disturbed perception, sleep disturbance, and cardiovascular disorders [30], [31]. Noise exposure can cause an increase in the release of stress hormones, imbalances in organ homeostasis, changes in the cardiovascular system and metabolism, and worsening risk factors for heart disease (high blood pressure, serum lipid disorders, blood viscosity), and increased blood glucose [32], [33]. Noise as an unpleasant sound, so that disturbs humans physically and physiologically [34], [35]. The noise was a general health hazard in the workplace that causes discomfort, to stress to exhaustion. It is natural that in some studies, the noise was the most challenging feature to handle, because of this subjective phenomenon [36], [37].

3.5. Relationship and Effect of Age on Work-fatigue

The results of the calculation of the correlation value and age t-test on work-fatigue produce a p-value of 0.001 (p ≤ 0.05) and a value of t-value 3.493 > t-table 1.989. This value shows that age has a relationship and a significant effect on work-fatigue.

More workers in this age range can potentially increase work productivity. This condition was an advantage for the company. If the worker is in the age range, then work productivity decreases, because the body has undergone tissue changes, so the body's strength has decreased. Age can affect maximum power in one's muscles, where the peak of muscle tightness is in the age range of 25-35 years, and one's muscle strength will decrease by around 15-25% in the age range of 50-60 years [38]–[40].

As humans get older, the feeling of fatigue a person feels will get faster. They are usually caused by a decreased physical state such as sharp eyesight, hearing, the speed of distinguishing things, making decisions, and the ability to remember short-term [41].

3.6. Relationship and Effect of Working Experience on Work-fatigue

Based on a statistical analysis of correlation and t-test work period of work, fatigue produces a p-value of 0.000 (p ≤ 0.05) and a t-value of 3.916 > t-table of 1.989. That value means the years of service have a relationship and have a significant effect on work-fatigue.

The working experience was one of the factors causing work-fatigue. Because the longer a person works will increase a feeling of saturation that is felt because the job done is monotonous and carried out repeatedly. Longer work will cause fatigue and boredom. The longer a person works, the faster the
adaptation process. This condition causes the pressure felt by workers to be more constant. This adaptation process provides both positive and negative effects for workers, where the positive impact is that it can improve work performance or increase work activities and can reduce tensions felt by workers. While the adverse effect is the body’s resistance will decrease with a growing work period so that the body feels tired quickly. Benefits for industries with experienced workers in completing their work so that obstacles in working can be rapidly overcome. The longer a person works, the more qualified he is in doing his job [42]–[45].

3.7 Relationship and Effect of Marital Status on Work-fatigue
Based on the statistical analysis, the correlation of marital status to work-fatigue yields a p-value of 0.189 (p> 0.05). Marital status can affect the quality of work, both positive and negative influences. The positive effect is that married workers will be more enthusiastic about doing their job because of the support and encouragement of the family and the desire to make their family happy. In contrast, the negative effect of married workers on the quality of work will decrease because family problems will affect the worker. In this study, marital status did not have an impact on work-fatigue at the crumb rubber plants of Padang.

3.8. Relationship and Effect of Education on Work-fatigue
Based on a statistical analysis of correlation and t-test, the level of education on work-fatigue produces a p-value of 0.408 (p> 0.05) and a t-value of -0.832 < t-table 1.989. The level of education was proportional to the quality of work. The higher one's knowledge, the wider the way of thinking, the power of initiative becomes more elevated, and it is easier for someone to find efficient ways of completing their work so that the quality of their work also increases. In this study, there was no significant relationship between education level and work exhaustion.

3.9. Multiple Regression Analysis
Based on variables that have an influence on work-fatigue, a multiple regression test is performed to see the odd ratio that affects work-fatigue in this study. Table 3 shows the results of these calculations.

| Variables          | Odds Ratio |
|--------------------|------------|
| Noise \((X_1)\)    | 3.92       |
| Age \((X_2)\)      | 0.25       |
| Work Experience \((X_3)\) | 1.79     |
| Another Factor     | 15.33      |

Table 3 shows that the noise variable has the most significant influence at 3.92 times compared to other variables in affecting work-fatigue at these three crumb rubber plants. So the higher the noise level, the higher the potential for work-fatigue in workers.

Noise control efforts that can be done are:
1. Control of the noise source by insulating the source and replacing the use of the machine with more noise-friendly technology;
2. Control over the distance between the source and the worker/receiver. The industry can provide insulation and shielding between workers and noise sources. In addition, the industry can use automatic machinery;
3. Control of workers/recipients. The industry increases the discipline of workers in using PPE that has been given. Besides, the industry can also regulate and reduce work time by rotating the work area until the shift time.
4. Conclusions
The average level of noise that occurs in the production area of three crumb rubber plants of Padang was 90.98 dB already exceeding the TLV set by the Regulation of the Indonesian Health Ministry Number 70 of 2016. Percentage of the level of work-fatigue that occurs in the production area was light work-fatigue 26.19%, moderate work-fatigue 71.43% and heavy work-fatigue 2.38%. Noise, age, and length of work were related and significantly influence work-fatigue, where the p-values were 0.046, 0.001, and 0.000, respectively (p≤0.05). The multiple regression results explain that noise was the most influential factor in the occurrence of work-fatigue, with an odds ratio of 3.92.

Acknowledgments
This research was supported by Research and Community Service Institutions (LPPM), Universitas Andalas, Padang. The authors are very grateful to all the participants who joined in the study.

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