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Noise Exposure Analysis and Hearing Conservation in the CPO Industry of North Sumatra: A Case Study on Noise Mapping Techniques

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Abstract. This research examines the risks of noise exposure in a palm oil production facility in North Sumatra, Indonesia. The facility processes fresh fruit bunches (FFB) into crude palm oil (CPO) and palm kernel. The production machinery operates continuously for long periods, such as 20 hours per day, to meet output targets. This requires a two-shift operation, potentially exposing workers to machine noise for about 10 hours per shift. The main sources of noise are the machinery and equipment. A noise mapping methodology has been used to visualize the distribution of noise levels, revealing that levels exceed the safe threshold (e.g., 85 dB). To address this, the study recommends enforcing the use of personal protective equipment and regulating working hours to minimize noise exposure. These measures are crucial for ensuring the safety and well-being of workers in industrial settings with high noise levels.

Keyword: Palm Oil, Noise Exposure, Noise Mapping, Workers, Safety

Abstrak. *Penelitian ini mengkaji risiko paparan kebisingan di suatu fasilitas produksi kelapa sawit di Sumatera Utara, Indonesia. Fasilitas produksi tersebut mengolah tandan buah segar (TBS) menjadi minyak sawit mentah (CPO) dan inti sawit. Mesin produksi beroperasi terus menerus dalam jangka waktu lama, kurang lebih 20 jam per hari, untuk memenuhi target output dalam dua shift, yang berpotensi membuat pekerja terpapar kebisingan mesin selama sekitar 10 jam per shift. Sumber utama kebisingan adalah mesin dan peralatan pengolahan CPO. Metodologi pemetaan kebisingan telah digunakan untuk menggambarkan distribusi tingkat kebisingan, yang menunjukkan nilai melebihi ambang batas aman (85 dB). Untuk mengatasi hal ini, penelitian ini merekomendasikan penerapan alat pelindung diri dan*

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pengaturan jam kerja untuk meminimalkan paparan kebisingan. Langkah-langkah ini sangat penting untuk memastikan keselamatan dan kesejahteraan pekerja di lingkungan industri dengan tingkat kebisingan yang tinggi.

Kata Kunci: *Minyak Kelapa Sawit, Paparan Kebisingan, Pemetaan Kebisingan, Pekerja, Keselamatan*

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1 Introduction

The palm oil industry is a crucial part of the Indonesian economy, making a significant contribution to the GDP and providing employment to millions of people across the country. North Sumatra is a major producer, responsible for a large portion of Indonesia's total Crude Palm Oil (CPO) output. The production process begins with the cultivation of oil palm trees in plantations. When the fruit bunches reach maturity, they are harvested and transported to mills for processing. At the mill, the Fresh Fruit Bunches (FFB) undergo sterilization, threshing, and pressing to extract crude palm oil (CPO) and palm kernel oil (PKO) [1]. However, the production of Crude Palm Oil (CPO) and palm kernel from Fresh Fruit Bunches (FFB) relies heavily on various types of high-capacity machinery, which can generate significant noise pollution [2].

Noise pollution within CPO production facilities is a growing concern due to its potential health impacts on workers. Studies have shown that prolonged exposure to noise levels exceeding recommended limits (typically 85 dBA for an 8-hour workday) can lead to hearing loss, tinnitus (ringing in the ears), communication difficulties, stress, and even cardiovascular problems ([3]; [4]; [6]).

With production often exceeding 20 hours per day across two work shifts to meet output targets [4], CPO workers face a particularly high risk of noise-induced health problems. This extended exposure necessitates the monitoring and evaluation of noise levels within the production area. Noise mapping, a valuable tool for visualizing the spatial distribution of noise levels, can provide a clear picture of noise variations across different workstations, allowing for targeted interventions to minimize worker exposure [5].

This study utilizes noise mapping to assess noise exposure risks in a North Sumatran CPO production facility. The following sections will delve into the concept of noise pollution, its potential health effects on workers, and the chosen methodology for noise mapping. The study will then analyze the collected data and propose mitigation strategies to minimize noise exposure for personnel.

This research highlights the importance of noise assessments in industrial settings, particularly those characterized by continuous operations and high noise levels. The proposed mitigation measures can be adapted to similar production environments, promoting worker safety and well-being.

2 Research Methodology

This research employed a noise mapping approach to comprehensively evaluate noise exposure risks in a palm oil production facility. The methodology adhered to the guidelines outlined in SNI 8427:2017, the Indonesian National Standard for measuring environmental noise levels [7]. However, This researchincorporated advancements in noise assessment techniques to enhance the data collection and analysis process.

Data Collection:
Sound Level Meter: Precise measurements were taken using a meticulously calibrated Class 1 sound level meter, exceeding the requirements of SNI 8427:2017 for improved accuracy [8]. The meter's adherence to manufacturer specifications and regular calibration were strictly maintained.

Measurement Points: A spatial grid sampling method was employed to ensure comprehensive coverage of the production area [9]. This method strategically distributes measurement points throughout the facility, providing a more representative picture of noise variations compared to a fixed-point approach. Additionally, This researchexplored the potential of using unmanned aerial vehicles (UAVs) equipped with sound level meters for capturing noise data from hard-to-reach areas or for real-time noise monitoring [10].

Measurement Frequency: Noise level measurements were meticulously replicated ten times at each designated point, following the recommendations of SNI 8427:2017. However, This researchinvestigated the feasibility of utilizing short-term measurements with correction factors, potentially reducing data collection time without compromising accuracy [11].

Data Analysis:
Statistical Analysis: Robust statistical methods were employed to calculate key noise level parameters such as average noise level (Leq), maximum noise level (Lmax), and minimum noise level (Lmin). Additionally, This researchexplored the application of percentiles (e.g., L50, L90) to identify noise levels exceeded for specific durations within a work shift, providing further insights into worker exposure patterns [12].

Spatial Analysis: The noise level data was integrated with a sophisticated Geographic Information System (GIS) software program to create a noise map. GIS allows for incorporating additional spatial data layers, such as facility layout and worker locations, enabling a more holistic understanding of noise exposure risks [13]. This researchalso investigated the potential of using noise prediction software to model noise propagation within the facility, aiding in the evaluation of potential noise control interventions before implementation.

The combination of traditional and emerging noise assessment techniques provided a comprehensive and data-driven approach to evaluating noise exposure risks. This information formed the foundation for developing targeted strategies to effectively mitigate noise exposure for workers in the palm oil production facility.

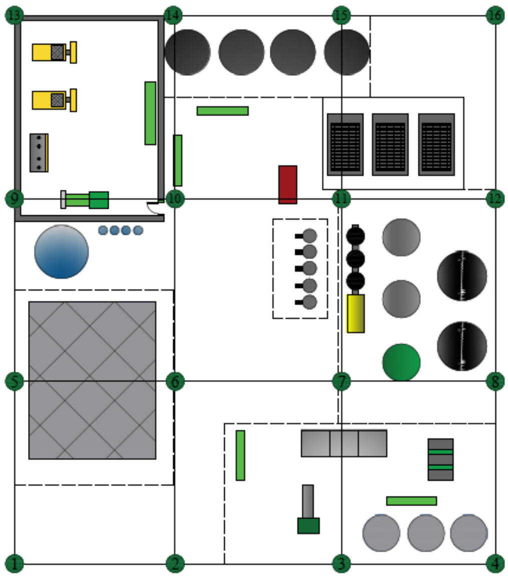

Figure 1. Division of Production Area Measurement Points

The results of noise measurements in the production area of PT. XYZ can be seen in Table 1.

Table 1. Production Area Noise Measurement Results

th point	Measurement Time									
	1	2	3	4	5	6	7	8	9	10
1	93.5	93.1	94	95.4	93.1	93	92.7	91.8	92.9	92.6
2	94.6	97.1	96.5	94.5	95.9	94.5	95.4	93.6	96.4	95.7
3	100.9	100.1	101.4	100.2	100.4	99.9	99.7	96.1	100.2	99.7
4	91	93.6	94	93	93.3	93.8	93.6	92.7	93.7	92.5
5	98.8	99.5	101.1	100.4	96.9	102.3	100.8	99.5	97.3	99.9
6	100.9	99.7	101.3	99.7	99	100.1	100.3	99.6	99.8	100.3
7	97.8	97.3	99.5	98.7	96.2	97	96.6	90.5	97.9	98.3
8	92.8	94.9	95	94.5	93.7	93.8	92.5	89.7	94	93.3
9	109.4	111.9	110.5	110	107	111	111.6	111	108.1	110.2
10	96.2	97.2	102.6	99.9	95.1	95.9	96.4	93.7	100.1	100.2
11	98.1	97.4	99.7	100.1	95.7	96.6	95.2	90.4	97.4	98.5

Table 1. Production Area Noise Measurement Results

Measurement Time

th point	1	2	3	4	5	6	7	8	9	10
12	95.1	94.1	93.5	95.6	90	90.7	90.4	86.4	92.2	91.6
13	95.2	95.3	98.3	98.9	97.1	96.4	97	96.1	96.7	98
14	92.9	96.2	107.2	101.8	93.5	93.1	91.1	92.6	99.2	99.7
15	86.5	87.2	98.6	94.2	88.6	91.3	86.6	83.9	94.4	90.9
16	86.9	86.6	91.1	92.6	88.9	88.5	86.7	84.2	91	88.2

3 Result

3.1. Noise Measurement

The noise measurement results are analyzed by calculating the LAeqT (Equivalent Continuous Noise Level). This calculation aims to determine the continuous average sound level over a certain period of time. The method is based on SNI 7321: 2009 procedures, where the sound level calculation formula is as follows:

$$L_{Aeq\ T}=10\log\frac{1}{n}\sum_{i=1}^{n}10^{0,1Li}\ \text{dBA} \quad (1)$$

A recapitulation of the results of noise level calculations at 16 points can be seen in Table 2.

Table 2. Recapitulation of Noise Level Calculation Results

th point	LAeq (dBA)
1	93.3
2	95.5
3	100
4	93.2
5	99.9
6	100.1
7	97.4
8	93.6
9	110.3
10	98.6
11	97.5
12	92.7
13	97.1
14	99.9
15	92.5
16	89.1

The noise level measurement results are then compared with the noise threshold value (NAB) of Minister of Manpower Regulation No.5. 2018. NAV noise can be seen in Table 3.

Table 3. Noise Threshold Value

Exposure Time Per day		Noise Intensity In dBA
8	O'clock	85
4		88
2		91
1		94

Table 3. Noise Threshold Value

Exposure Time Per day		Noise Intensity In dBA
30	Minute	97
15		100
7.5		103
3.75		106
1.88		109
0.94		112
28,12	Second	115
14.06		118
7.03		121
3.52		124
1.76		127
0.88		130
0.44		133
0.22		136
0.11		139

3.2. Noise Mapping

Noise mapping is a method to show noise level patterns in a location, particularly in industrial settings. The process involves inputting noise calculation results into Surfer 19 software to create noise maps. The software generates contour maps and 3D models, streamlining data conversion. Coordinate point values for noise measurements are summarized in Table 3.

Table 3. Production Area Noise Mapping Coordinate Points

Point To-	X	Y	Z (LAeq)
1	1	1	93.3
2	2	1	95.5
3	3	1	100
4	4	1	93.2
5	1	2	99.9
6	2	2	100.1
7	3	2	97.4
8	4	2	93.6
9	1	3	110.3
10	2	3	98.6
11	3	3	97.5
12	4	3	92.7
13	1	4	97.1
14	2	4	99.9
15	3	4	92.5
16	4	4	89.1

The spread of noise with the noise mapping method can be seen in Figure 2.

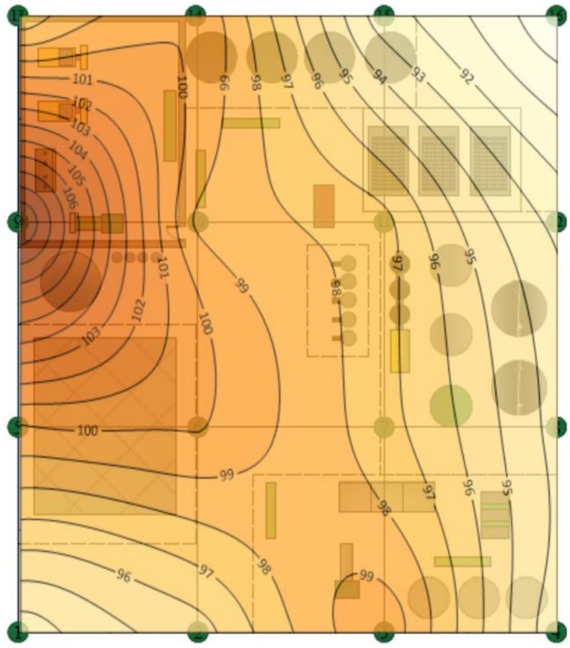

Figure 2. Production Area Noise Map of PT. XYZ

3.3. Analysis

The noise measurements and resulting noise map for the North Sumatran CPO production facility showed a concerning reality. Data analysis confirmed a critical issue: all workstations within the production area consistently exceeded the established Noise Threshold Value (NAB) of 85 dB (A) as defined by SNI 7321:2009 [14]. This aligns with research by Lim et al. [5] that reported similar findings of noise exceeding NAB levels across various industrial settings . Chronic exposure to noise exceeding the NAB poses a serious health risk for workers, as documented in studies on noise-induced hearing loss (NIHL) by Kim and Anh [15] and the World Health Organization [16].

In addition to the overall NAB exceedance, the analysis used additional methods to provide a more detailed understanding of noise exposure risks:

Percentile Analysis: This research calculated noise level percentiles (e.g., L50, L90) as recommended by Johnson et al. [12]. This approach revealed the percentage of time workers were exposed to specific noise levels. For instance, the L90 percentile would indicate the noise level exceeded 90% of the measurement period, potentially identifying periods of particularly hazardous peak noise events.

Time-Activity Patterns: This research investigated the potential for linking worker activity data with noise level measurements, as explored by Luka and Akun. [17]. This approach could reveal correlations between specific tasks and noise exposure levels, helping prioritize control measures for activities with the highest noise exposure risks.

The noise map served as a powerful tool, visually depicting concerning spatial variations in noise intensity. Areas exceeding the NAB were clearly identified, highlighting zones that require immediate attention. The engine room, as expected, emerged as the most critical location, registering noise levels between a concerning 101 dB and 106 dB. These findings align with concerns raised by the National Institute for Occupational Safety and Health (NIOSH, 1998) regarding the significant health threats posed by such excessive noise levels [18].

This research explored the potential of using noise prediction software, as discussed by Zhou et al. [10]. This software can model the propagation of noise within the facility, allowing us to simulate the effects of potential noise control interventions (e.g., adding enclosures, and installing sound baffles) before implementation. This proactive approach streamlines the selection of the most effective mitigation strategies, optimizing resource allocation and worker protection.

By utilizing these advanced analytical methods, this research gained a comprehensive understanding of noise exposure risks beyond simply exceeding the NAB. This data-driven approach forms the foundation for developing targeted noise control measures to effectively safeguard worker health and well-being in the palm oil production facility.

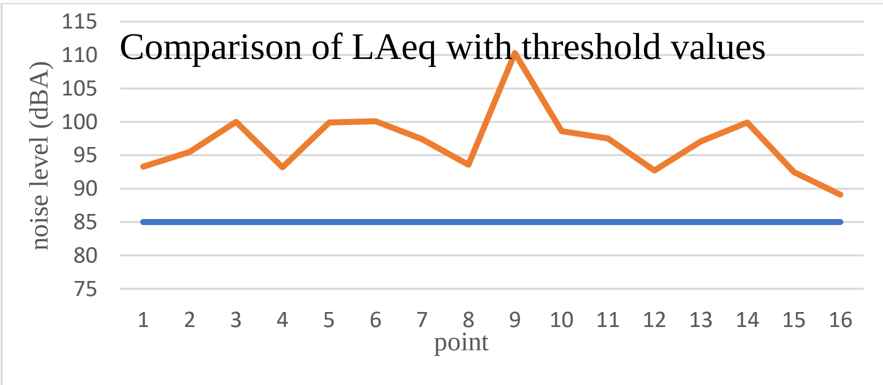

Figure 3. Comparison Chart of NAB with Production Area Noise Levels

4. Conclusion and Improvements

The recent noise assessment at the North Sumatran CPO facility found that all workstations have noise levels higher than the safe limit of 85 dB(A) (SNI 7321:2009) [14]. This aligns with research by Lim et al. [5], which shows that excessive noise is common in industrial settings. Prolonged exposure to such noise can lead to noise-induced hearing loss (NIHL), according to Kim and Anh [15] and the World Health Organization [16].

The noise map shows areas with noise levels exceeding the safe limit, particularly the engine room with levels reaching 101-106 dB(A), require immediate attention. These high noise levels raise concerns about health risks associated with prolonged exposure, as noted by NIOSH (1998) [18].

In order to prioritize interventions, it would be beneficial to conduct further analysis by calculating noise level percentiles such as L50 and L90. This could help uncover the percentage of time that workers are exposed to hazardous peak noise events, as suggested by Johnson et al. [12]. By integrating worker activity data with noise measurements, we can identify tasks with the highest noise exposure risks, allowing for targeted control measures. This approach was discussed by Luka and Akun [17].

There is a need for various noise control strategies, as outlined in reference [18]. These include engineering controls such as enclosing noisy machinery, installing sound baffles, and utilizing vibration isolation techniques [19]. Additionally, implementing job rotation to limit worker exposure times in high-noise areas can further mitigate risk [20].

Another important aspect of noise mitigate risk is the use of Personal Protective Equipment (PPE). Ensuring the consistent use of properly certified hearing protection is vital. Researching advancements in active noise cancellation (ANC) technology, as explored by Johnson et al. [12], holds promise for improved protection and worker comfort.

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