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Assessment of Occupational Noise Exposure in Industrial Environments: A Case Study in Metal Casting

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Abstract. Good work environment conditions can affect the increase in worker productivity. One of the work environment factors that needs to be considered is distraction. Noise problems not only interfere with concentration but can also damage workers' hearing and reduce overall work safety. Therefore, this study aims to analyze the noise level in the work area in the production process of a company engaged in the metal casting industry and provide recommendations that can reduce the negative impact on the workforce. This measurement uses Decibel X with a time interval of five seconds, and then data processing is carried out to determine the LTm5 value. The measurement results show that the level of disturbance in some work areas exceeds the recommended threshold, increasing the risk of worker health problems. To reduce this negative impact, the study provides the provision of personal protective equipment (PPE), such as earplugs, as well as the implementation of occupational safety and health (OHS) socialization. This research makes an essential contribution to the management of nuisance risks in industrial environments, especially in improving worker safety and health through effective mitigation strategies.

Keywords: Industrial safety standards, Noise exposure, Occupational health hazards.

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1. Introduction

Inefficient activities in the production process often lead to waste, which needs to be eliminated to minimize problems along the production floor [1]. This waste can occur when there are delays in raw materials in the production process, which can affect other processes and ultimately harm the company [2]. Therefore, every company is required to have its quality standards to ensure that the products produced are acceptable to consumers [3]. For this reason, it is essential to identify the types of waste in each stage of production in order to improve efficiency and reduce losses that may occur [4]. With systematic improvements, companies can maintain their productivity while reducing the negative impact of external factors, such as noise generated by industrial activities. Environmental noise generated by human activities, such as transportation, industry, and other commercial activities, has increased significantly in recent decades [5]. In industrial environments, noise is one of the main challenges arising from operational activities, such as the sound of machinery and production processes [6, 7, 8]. In addition, it can disrupt interactions between workers and reduce work safety and comfort [9, 10]. Disturbing industrial noise can generally be classified into four main groups, namely: continuous machine noise, repetitive actions at high speed that produce strong-pitched sounds, flow-induced noise, and the impact of work tools on workpieces [11]. This noise often occurs in cramped production areas, to which workers are exposed for long periods [12].

Noise is one of the most common physical factors that cause annoyance and jeopardize workers' health and operability [13, 14]. Long-term professional exposure to noise can adversely affect hearing, the cardiovascular system [15], stress, fatigue [16], and biochemical and physiological changes in humans and animals [17]. Noise can also reduce job performance, as some attempts to adapt can destabilize sentiment changes and cause blood vessels to clog, increase blood pressure, and reduce circulatory system volume [18]. The impact of non-optimal workplace conditions leads to decreased work performance [19, 20].

Noise exposure limits in the workplace are generally based on the assumption that employees work eight hours a day for five days a week. The average sound pressure level for an eight-hour workday, i.e., the daily noise exposure level (or so-called Lex, eight hours), is measured to determine whether it complies with the law [21]. In addition, various industrial sectors such as processing and manufacturing, mining, and oil and gas often have high noise levels with intensities of more than 85 dB(A), which can be risky for workers' health [11, 22]. Noise with increasing frequency generally only affects the range of operations. In contrast, noise with specific frequency peaks can disrupt the performance of industrial systems and cause operational errors if not adequately addressed [23].

In this company, most of the production still relies on human labor, but there are unsupportive work environment conditions, namely high noise levels. This condition can affect labor productivity, potentially reducing the amount of production. Therefore, this study was conducted to analyze the company's physical work environment, especially the noise factor in the production process room, with the aim of providing recommendations for workers.

Research conducted [14] highlights the importance of noise level analysis in the context of modern manufacturing companies. At the same time, [24] discussing heat and noise exposure in manufacturing plants located in countries with hot and humid climates. However, these two studies have yet to specifically investigate the noise conditions in a predominantly human and heat-driven work environment in the metal casting industry. The foundry industry has unique working environment characteristics, with high temperatures and more intensive noise due to the liquid metal production process and the use of heavy machinery. The metal casting industry has unique working environment characteristics, with high temperatures and intensive disturbances from the molten metal production process and heavy machinery. Excessive noise can cause health problems such as hearing loss and fatigue, as well as reduce work efficiency. Souza et al. [7] stated that the Ishikawa approach can help identify the causes of disturbances and reduce their impacts. Previous studies, such as those by Gajdzik et al. [9], have shown that disturbances in the industrial sector often exceed safety standards, including in heavy manufacturing. Wojtyto et al. [14] also noted that disturbances are the main physical factors that have a negative impact on workers' health. However, studies on disturbances in the metal casting industry are still rare. This research focuses on filling this gap by measuring noise levels and heat exposure in foundries and providing appropriate mitigation recommendations to improve worker safety and comfort.

Better design and protection against noise can improve clarity and operational efficiency [25]. Noise reduction can also be achieved through absorption, vibration reduction, and damping methods [26]. A safe, comfortable, and healthy workplace environment is essential in ensuring good employee productivity [24]. This research is vital to reducing the risk of occupational accidents due to continuous noise exposure.

2. Research Method

2.1. Object and Subject of Research

The object of this research is the noise level of the production process section, with the subject of research on noise sources in the metal casting industry production process section.

2.2. Research Flow

The research begins by identifying and formulating the problem. Then, literature and field studies are conducted, and data are collected and measured using the Decibel X. Next, the noise from the measurement results is analyzed. Finally, conclusions and suggestions are provided based on the data analysis.

2.3. Noise Measurement

Noise measurement was conducted during the production process at five different points: the melting section, the machining section, the fettling section, the mold-making section, and the unloading section. This measurement process uses a time interval of five seconds. The five-second interval was chosen because it adequately represents the noise fluctuations at each point of the production process, given the dynamic nature of the activities. The five measurement points were determined based on the dominant noise-generating activities so that the results can represent the overall noise variation and identify the primary sources that need to be addressed. Furthermore, data processing is carried out by calculating the range, number of classes, class intervals, frequency distribution, and the final results in the form of values.

3. Results and discussion

3.1. Noise Data

Table 1 shows the noise data measured using the Decibel X with a measurement interval of every five seconds. This data provides an overview of the noise levels recorded during the observation period and can be used to analyze the impact of noise on the working environment.

Table 1. Noise Data

Amount of data	Melting (dB)	Machining (dB)	Fettling (dB)	Print (dB)	Unload (dB)
1	76.6	73.0	93.0	73.9	79.0
2	79.4	72.1	94.2	74.1	78.6
3	80.4	72.7	80.5	75.2	90.4
4	81.1	79.7	81.7	77.8	81.1
5	82.3	79.7	80.3	79.1	82.3
6	83.0	78.7	85.5	79.6	83.0
7	81.7	78.9	84.3	73.6	92.3
8	70.7	77.9	82.7	73.0	81.7
9	71.7	77.8	84.2	74.5	70.7
10	75.1	78.3	88.9	73.7	71.7
11	78.2	79.0	91.5	73.1	75.1
12	84.1	79.8	87.5	74.1	78.2
13	83.7	77.2	89.4	74.1	84.1
14	81.0	73.8	85.2	77.9	83.7
15	83.3	75.0	91.2	76.8	81.0
16	85.0	76.2	88.3	75.9	83.3
17	83.8	76.8	84.3	71.2	85.0
18	77.6	77.6	87.3	71.0	83.8
19	79.7	78.8	89.9	75.8	84.4
20	81.4	78.2	88.2	75.6	77.6
21	80.6	76.4	86.8	73.8	81.4
22	81.6	77.0	85.3	77.0	86.1
23	84.4	75.6	87.2	68.8	85.6
24	83.2	74.6	88.2	77.0	88.8
25	88.8	74.8	89.1	72.4	70.0
26	85.6	76.6	90.0	70.2	87.9
27	70.1	79.1	93.6	70.8	90.0
28	78.3	80.3	89.3	68.6	90.3
29	77.6	82.6	92.4	67.0	91.7
30	80.5	80.7	82.4	71.2	89.9
31	80.6	80.0	95.3	79.2	85.7
32	81.2	81.8	96.2	78.9	85.3
33	79.1	80.9	86.0	75.1	83.9
34	78.9	81.1	100.7	73.7	84.1
35	79.3	82.3	101.7	74.5	84.8
36	80.3	81.8	92.3	76.1	79.1
37	81.0	82.0	97.8	75.7	78.9
38	78.7	75.5	87.7	78.8	79.3
39	81.2	76.0	88.3	79.6	78.7
40	83.9	77.0	86.0	79.3	85.9
41	84.1	78.9	85.9	69.8	89.9

Amount of data	Melting (dB)	Machining (dB)	Fettling (dB)	Print (dB)	Unload (dB)
42	82.7	74.4	89.7	68.8	79.6
43	79.9	79.5	90.8	67.9	80.1
44	80.1	80.2	91.9	68.1	82.0
45	80.3	81.3	82.8	67.1	82.2
46	85.7	79.4	90.0	70.3	85.7
47	80.1	72.5	88.8	71.3	87.9
48	80.3	74.2	88.3	71.2	83.2
49	81.3	73.6	89.4	75.9	80.0
50	79.7	73.9	89.8	74.9	78.9

3.2. Noise Measurement

Based on the 250 data that have been collected from the five points of the process room, the following calculations will be made with L_{Tm5}:

1. *Melting*

- Calculate the range (r)
  r = 18.7 dB
- Calculating the number of classes (k)
  K = 6,6 = 7
- Calculating class interval (i)
  i = 2,6 ≈ 3
- Calculating the frequency distribution

Next is the pattern of noise levels in the melting chamber. The noise range is divided into different intervals, each with a cut-off value representing the noise level within a specific range. The frequency distribution shows the amount of noise recorded within each interval. Details of the frequency distribution can be seen in Table 2.

Table 2. Melting Frequency Distribution

No	Noise Interval	Center Value	Frequency
1	70.1- 72	71.5	3
2	72.1 -75.1	73.6	1
3	75.2 - 78.2	76.7	4
4	78.3 - 81.3	79.8	24
5	81.4 - 84.4	82.9	14
6	84.5 - 87.5	87	3
7	87.6 - 90.6	88.6	1

- Calculating L_{Tm5}
  $L_{Tm5} = 10 \times (Log(\frac{1}{n} \times (\sum Tn.10^{0,1Ln})))$
  L_{Tm5} = 81,76dB(A)

2. *Machining*

- Calculating the range (r)
  r = 10 dB
- Calculating the number of classes (k)
  K = 6,6 = 7
- Calculating class interval (i)
  i = 1,42 ≈ 1,5
- Calculating the frequency distribution

The frequency distribution provides an overview of the noise patterns in the machining room. It is divided into several intervals that indicate that the noise level is recorded within the range and frequency of occurrence. The machining frequency distribution can be seen in Table 3.

Table 3. Machining Frequency Distribution

No	Noise Interval	Center Value	Frequency
1	72.1 – 73.6	72.8	5
2	73.7 – 75.2	74.4	8
3	75.3 – 76.8	76	7

4	76.9 – 78.4	77.7	6
5	78.5 – 80.0	79.3	12
6	80.1 – 81.6	80.8	6
7	81.7 – 83.2	82.4	5

- Calculating L_{Tm5}
  $L_{Tm5} = 10 \times (Log(\frac{1}{n} \times (\sum Tn. 10^{0,1Ln})))$
  L_{Tm5} = 78,61dB(A)

3. *Fettling*

- Calculating the range (r)
  r = 21.4 dB
- Calculating the number of classes (k)
  K = 6,6 = 7
- Calculating class interval (i)
  i = 3,05 ≈ 3
- Calculating frequency distribution

The frequency distribution provides an overview of the noise patterns in the Faitling room. It divides the noise into several intervals, indicating the noise levels recorded within that range and the frequency of occurrence. The frequency distribution in the fellting room can be seen in Table 4.

Table 4. Fellting Frequency Distribution

No	Noise Interval	Center Value	Frequency
1	80.3 – 83.3	81.8	5
2	83.4 – 86.4	84.9	9
3	86.5 – 89.5	88	17
4	89.6 – 92.6	91.1	11
5	92.7 – 95.7	94.2	4
6	95.8 – 98.8	97.3	2
7	98.9 – 101.9	100.4	2

- Calculating L_{Tm5}
  $L_{Tm5} = 10 \times (Log(\frac{1}{n} \times (\sum Tn. 10^{0,1Ln})))$
  L_{Tm5} = 91,56dB(A)

4. Molding

- Calculating the range (r)
  r = 12.6 dB
- Calculating the number of classes (k)
  K = 6,6 = 7
- Calculating class interval (i)
  i = 1.8 ≈ 2
- Calculating frequency distribution

The frequency distribution provides an overview of the noise patterns recorded in the Mold room. This distribution process divides the noise into several intervals, each of which describes the noise level within a specific range as well as its frequency. Table 5 displays the frequency distribution for the Mold room.

Table 5. Mold Frequency Distribution

No	Noise Interval	Center Value	Frequency
1	67.0 – 69.0	68	7
2	69.1 – 71.1	70.1	5
3	71.2 – 73.2	72.2	7
4	73.3 – 75.3	74.3	13
5	75.4 – 77.4	76.4	8
6	77.5 – 79.5	78.5	8
7	79.6 – 81.6	80.6	2

- Calculating L_{Tm5}
  $L_{Tm5} = 10 \times (Log(\frac{1}{n} \times (\sum Tn.10^{0,1Ln})))$
  L_{Tm5} = 75,33dB(A)

5. *Unloading*

- Calculating the range (r)
  r = 22.3 dB
- Calculating the number of classes (k)
  K = 6,6 = 7
- Calculating class interval (i)
  i = 3.18 ≈ 3
- Calculating frequency distribution

The frequency distribution illustrates the pattern of noise recorded in the unloading room. The noise is divided into intervals, indicating the noise level within each range and the frequency of occurrence. Table 6 presents the frequency distribution for the unloading room.

Table 6. Frequency Frequency Distribution

No	Noise Interval	Center Value	Frequency
1	70.0 – 73.0	71.5	3
2	73.1 – 76.1	74.6	1
3	76.2 – 79.2	77.7	8
4	79.3 – 82.3	80.8	11
5	82.4 – 85.4	83.9	12
6	85.5 – 88.5	87.0	8
7	88.6 – 91.6	90.1	5

- Calculating L_{Tm5}
  $L_{Tm5} = 10 \times (Log(\frac{1}{n} \times (\sum Tn.10^{0,1Ln})))$
  L_{Tm5} = 85,59dB(A)

3.3. Noise Data

The results of measuring the noise level using Decibel X by taking 50 data every five seconds provide an overview of the noise level in various production rooms as follows:

1. Melting room: The L_{Tm5} of 81.76 dB(A) was obtained, indicating that the noise is high enough to potentially affect workers' concentration and comfort, especially due to metal melting activities involving high temperatures and large equipment.
2. Machining room: The L_{Tm5} of 78.61 dB(A) was obtained, indicating that the atmosphere in the machining room is quite noisy. This can affect worker comfort and concentration, especially since activities in this room involve the use of precision machines such as lathe, milling, or drilling that produce repetitive mechanical sounds. This noise can also interfere with communication between workers, which increases the risk of operational errors if there are no adequate mitigation measures in place.
3. Fettling room: The L_{Tm5} is 91.56 dB(A) obtained, indicating conditions that are very risky to workers' hearing health. This may be due to intensive activities such as metal polishing or cutting that produce loud noises continuously.
4. Molding room: The L_{Tm5} of 75.33 dB(A) indicates that the mold room atmosphere is quite noisy. However, this value is still at a level that could potentially cause hearing loss if exposed for a long time. The processes that take place in the mold room, such as pouring molten metal into the mold and cooling, although they do not produce noise as loud as other spaces, still generate noise that needs to be managed.
5. Unloading room: The L_{Tm5} is 85.59 dB(A). This value indicates that the atmosphere of the unloading room is high in noise, which may come from the process of unloading materials or interaction with heavy equipment.

When compared to Oyedepo et al. [11] study, the noise level in the fettling room (91.56 dB(A)) is close to the highest average noise in some industries, such as vacuum pumps (93.1 dB(A)) in the tobacco industry. This emphasizes the need for effective noise control. Proposed mitigation strategies involve using earplugs in noisy areas, providing OSH training on PPE, and controlling noise through equipment assessment and sound-absorbing materials. This approach safeguards workers' hearing and enhances productivity and safety. However, the study's limitations include possible measurement bias due to noise fluctuations, requiring further measurements to confirm the findings.

4. Conclusion

Based on the LTM5 calculation with an interval time of every 5 seconds, the measurement results were obtained from each production room. In the melting room, the noise was recorded relatively high, indicating the potential for hearing loss for workers if exposed for a long time. Likewise, in the machining room, the atmosphere is quite noisy, which can affect the comfort and concentration of workers. Although the molding room has relatively lower noise, the atmosphere in this room is still quite loud and can affect workers' hearing health. Meanwhile, in the fettling room and unloading room, the noise is relatively high, so more attention is required to protect workers from the negative impacts of the noise. To mitigate these risks, companies should provide earplugs, conduct OSH training, and implement noise-reducing measures such as equipment upgrades and soundproofing. Policy adjustments to enforce stricter noise control in industrial environments are also recommended. Future research could focus on the effectiveness of various PPE types for different production areas and explore the psychological effects of noise on workers to guide policy improvements in worker welfare.

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