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Noise Mapping with Surfer Software as Noise Depiction in Water Treatment Plant PT. Z

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Abstract: PT Z operates in the production of clean water, which has the potential to generate noise due to machinery used in the processing process or clean water dosing system. Noise that occurs in the production area can affect the health and comfort of operators and visitors who are in the location. This study aims to identify noise levels, recommended exposure duration, areas exposed to noise, as well as analyze the causes of noise and provide proposals for its control. The noise measurement method used refers to the noise mapping method and uses a sound level meter. The data obtained was then processed into contour maps with purple, green, yellow, orange, and red color variations using Surfer 16 software. The results showed that the highest noise level reached 86.5 dB, while the lowest was 56.7 dB. Based on calculations using the NIOSH formula from 40 measurement points in the noise mapping method, there are 7 points that require increased noise control. The highest noise level was recorded at 86.5 dB with an exposure duration of 5.65 hours (393 minutes). Noise control efforts can involve three elements, noise sources, noise dispersal paths, and noise receivers, which are matched with the control hierarchy referenced from the Permenaker No. 5/2018.

Keywords: Noise depiction; Noise mapping; Surfer software

Introduction

Industrialization continues to grow rapidly due to technological advancements across various industries, even in the era of Society 5.0 (Tahar et al., 2022). The era of society 5.0 is one of the phases of change that can provide a lot of efficient changes to the development process and improve the quality of life of the community (Santoso et al., 2024). On the other hand, this era shows many tips for the community in improving skills and expertise that will bring many positive changes in future (Siregar et al., 2023). Society 5.0 envisions a future where the improvisation of skills and expertise can synergize with the creation of good technology used to solve social problems, improve the quality of human life, and have a positive impact on society and overall workers (Ramadhani et al., 2024). But in reality, the work environment in Indonesia still does not prioritize work safety because some companies are still considered taboo and there is no main focus on safety work (Muliyah et al., 2020). Some companies still think that using personal protective equipment (PPE) can overcome the possibility of occupational diseases and accidents due to work (Rahman, 2024).

Most of industries in Indonesia, noise is a frequently overlooked problem. Many companies, despite achieving production success, still do not fully address the negative impacts of noise on workers' health and productivity (Wati, 2020). Consequently, the work environment, which should be a safe and comfortable space, becomes a source of stress and health issues for employees. This excessive noise remains a common complaint among workers in the industrial sector (Afrizal, 2023).

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This situation underscores the importance of studying environmental noise, such as through noise mapping research (Singkam, 2020). By conducting this research, workers and management can identify noise-prone areas, enabling the implementation of effective control measures. One of the most feasible control strategies is administrative control, which involves regulating workers' exposure time in high-noise-level areas (Sari et al., 2024). This approach aligns with the hierarchy of hazard control, where administrative controls play a significant role in mitigating risks when elimination or substitution is not feasible.

Exposure to high noise levels can cause a variety of health issues, particularly hearing loss, as well as physiological and psychological disorders (Fariz, 2022). Workers in occupations with frequent exposure to high noise levels face an increased risk of conditions such as nausea, dizziness, sleep disturbances, balance disorders, and even permanent hearing loss. This emphasizes the critical need for noise exposure assessments, awareness programs, and protective interventions to safeguard workers' health and well-being (Dwisetyo et al., 2021).

The noise issue found in the Dosing System House section indicates that after initial measurements, the noise level in the area was around 89 dB. This emphasizes the importance of noise mapping as a tool to inform workers about the potential risk of occupational diseases caused by noise exposure in the dosing system house area. The results indicate that the noise levels in this area exceed the permissible noise threshold for industrial settings established by Indonesian government regulations, known as the Threshold Value, which is set at 85 dB by Minister of Manpower Regulation (Permenaker) 2018. It was also found that the noise exceeding this threshold occurs continuously for 24 hours. This situation is likely to cause health issues, including the risk of hearing loss. Therefore, it is essential to identify noise levels in the production area (Meilasari et al., 2021). The data collected can serve as a basis for analyzing noise control management strategies aimed at protecting workers from noise exposure (Tirta, 2020).

Solving this problem requires noise level mapping based on the noise mapping method. Noise mapping is a process that describes the distribution of noise levels in a production area (Ramadhan et al., 2023). In an industrial context, noise mapping is often used to estimate the noise distribution around a factory. The goal is to develop strategies that can control and reduce noise in compliance with applicable noise regulations (Nurdiyanto, 2022).

The purpose of this study is to measure the noise levels generated by production machines in the production area, analyze the comparison of these noise levels with the quality standards outlined in the Regulation of the Minister of Manpower and Transmigration of the Republic of Indonesia Number 13 of 2011, and calculate the maximum allowable exposure time to the noise level based on the NIOSH calculation method. Additionally, noise control recommendations will be developed based on the noise distribution map of the production area (Nurdiyanto, 2022).

Noise mapping will illustrate the importance of using earplugs for the comfort and safety of workers and visitors in the Water Treatment Plant area (Putri et al., 2021). It is hoped that this noise mapping can increase awareness, enhance productivity, and foster a better working environment for both workers and visitors (Ramadhani et al., 2024).

Method

This research using quantitative and qualitative descriptive research methods which are carried out by observation and measurement (Taherdoost, 2022). The research was conducted with the point of analyzing noise within the water treatment plant area. This research was conducted at the dosing system house, since this place has numerous production machines, so this building has the potential for noise risks that are more at hazard. The time of research and data collection was conducted in August 2024. The object of this research is noise sources within the form of production machines.

Data was obtained by observation and measurement. Noise measurement is carried out using a sound level meter (Khan & Burdzik, 2023). The way the sound level meter works is that if there's a vibration on an object, it causes a difference in air pressure so that it can be captured by this device and then can move the meter pointer. This measuring instrument can measure noise intensity between 30-130 dB (A) from a frequency of 20-20,000 Hz (Serpanos et al., 2021). The Sound Level Meter is equipped with three frequency measurement scales, namely: scale A, can show different sensitivity at low and high frequencies such as ear reaction at low intensity (35-135 dB); scale B, can show the sensitivity of the ear at medium intensity (40-135 dB); and scale C, can show ear sensitivity at high intensities (45-135 dB).

Observations are made by assessing whether this production area is still within the threshold value in accordance with the predetermined standards. After data collection and processing, the data that has been obtained is then processed in descriptive form in the form of a narrative explanation of the noise calculation carried out with applicable regulations and standards to facilitate understanding for the reader. In addition, later researchers will also provide recommendations as a form of contribution to noise knowledge in the company.

Research Instruments

In this research, the research instruments used are: manual Sound Level Meter set at a measurement range of 30 - 130 dB to measure the noise level; surfer 16 software to create noise contours; global Positioning System (GPS) to determine the coordinates of the measurement location; and meter tool to measure the grid distance in the field (Pődör & Szabó, 2021).

Noise Measurement Method

The tool used for measurement is the Sound Level Meter (SLM), which is set at a height of approximately 1 to 1.25 meters. The device is placed at predetermined measurement points. After obtaining the noise value at each measurement point, the noise levels are mapped using the Golden Surfer application to visualize and illustrate the noise distribution within the research area.

The study area measures 38.25 meters in length and 22.03 meters in width, resulting in a total area of 842.64 m². The analysis produced 200 data points, which were grouped into 40 measurement points spaced 5.5 meters apart in both length and width from adjacent points. The measurements were conducted during the afternoon work shift from 13:00 to 15:00, representing the broader shift from 10:00 to 18:00. This time frame was chosen to ensure that the water pump engine, booster pump, and CPI were operational, thereby capturing the maximum noise impact.

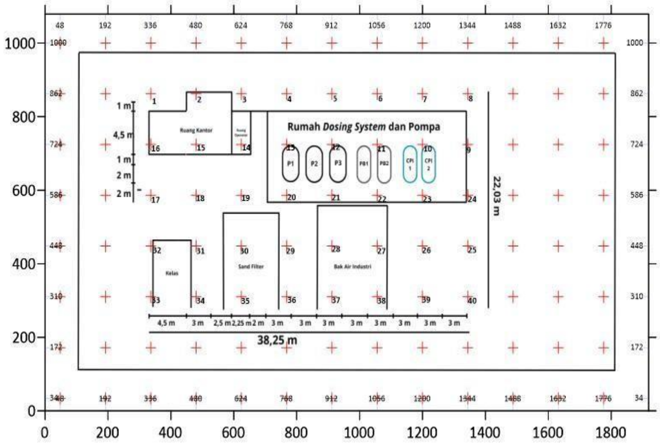

Figure 1. Layout and Measurement Point

The primary data collected in this study is the noise intensity generated by the water pump and CPI machines, which is used to assess their contribution to overall noise levels. Measurements followed the procedures outlined in SNI 8247:2017, where noise levels were recorded five times for one minute at each measurement point. The noise intensity at each point was calculated using the Formula 1.

$$Range = N_{max} - N_{min} \quad (1)$$

Description:
N_{max} = Highest value from 1 measurement point
N_{min} = Lowest value from 1 measurement point

$$Class = 1 + 3.3\,(\log n) \quad (2)$$

Description:
n = number of data in 1 measurement point

$$LAeq.T = 10\frac{1}{n}\log\sum Tn^{0.1xln}dB \quad (3)$$

Description:
LAeq.T = Equivalent continuous sound pressure level within 1 minute
LpAi = Instantaneous sound pressure level in 5-second intervals

Maximum Allowable Exposure Noise Level Calculation Method

The calculation of the length of time workers are exposed to noise is calculated using the following equation by (NIOSH, 2024).

$$T = \frac{480}{2^{(L-85)/3}} \quad (4)$$

Description:
T = maximum allowable exposure time at that point (minutes)
L = noise level at that point

Result and Discussion

Identification of Noise Sources

The results of noise measurements in the production area indicate that the primary noise sources originate from the operation of production machines used for water jetting or dosing systems. The noise sources are confined to the dosing system house, which includes: water pump machine: Responsible for moving water into the tub with sufficiently high pressure; booster pump machine: Assists in increasing water pressure to accelerate water transfer and eliminate blockages in the pipe; and CPI (Corrugated Plate Interceptor) machine: Separates oil, waste, and water using plates within the machine.

Noise Level Measurement Using the Grid Method

Noise measurements were conducted using 200 data points, with data processing performed in accordance with the SNI 8247:2017 standard to determine the noise level at each point. The measurement values for each point are presented in the following table. The results of noise measurements in the production area indicate that the primary noise sources originate from the operation of production machines used for water jetting or dosing systems. The noise sources are confined to the dosing system house, which include.

Table 1. Noise Value Every Sample Point

Sample Point	Noise values (dB)
1	62.3
2	64.0
3	71.3
4	70.6
5	69.8
6	69.7
7	69.3
8	66.2
9	72.1
10	78.8
11	80.8
12	81.6
13	86.5
14	67.8
15	65.0
16	61.4
17	63.7
18	67.8
19	74.9
20	79.1
21	79.6
22	77.6
23	75.8
24	70.9
25	65.3
26	70.1
27	68.5
28	68.5
29	69.6
30	67.0
31	63.8
32	61.9
33	56.7
34	60.1
35	64.0
36	66.2
37	66.0
38	66.0
39	67.1
40	63.8

Noise Level Distribution Pattern

Data processing was carried out using Surfer software. The distribution pattern of noise levels is categorized as follows: Light purple: Describes a noise level of < 61 dB; purple: Describes a noise level of 61.1 - 66 dB; Green: Describes a noise level of 66.1 - 71 dB; Yellow: Describes a noise level of 71.1 - 76 dB; Orange: Describes a noise level of 76.1 - 81 dB; Dark orange: Describes a noise level of 81.1 - 86 dB; and Red: Describes a noise level of > 86 dB.

After measuring at each point, the noise value is obtained. The results of noise level measurements can be examined and seen in the Table 2.

After obtaining the measurement points and numbers from the measurement results, we can visualize them in the form of a map. The results of data visualization are on the map shown in Figure 2.

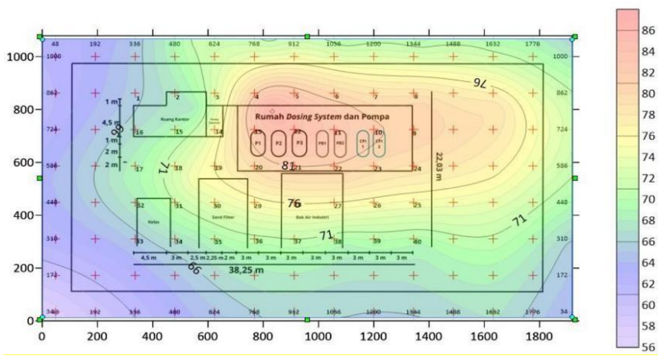

Figure 2. Noise Distribution Mapping

Exposure Time Analysis Using the NIOSH Formula

Based on the results of the noise level mapping in the production area, an analysis was conducted on measurement points grouped by noise intensity, specifically those that exceed the quality threshold (>85 dB) and those that do not (<85 dB), in accordance with the Minister of Labor Regulation No. 13 of 2011. To determine the safe duration of noise exposure, the NIOSH calculation method was applied.

$$T14 = \frac{480}{2^{(L-85)/3}} = \frac{480}{2^{(67.8-85)/3}}$$
$$T14 = 2553\ minutes = 42.5\ hours$$

$$T15 = \frac{480}{2^{(L-85)/3}} = \frac{480}{2^{(65-85)/3}}$$

$$T15 = 4876\ minutes = 81.3\ hours$$

NIOSH calculations were conducted at points 14 and 15, which represent areas where workers are frequently present, namely the office and operator room, with recorded noise levels of 67.8 dB and 65 dB, respectively. The results of the calculation indicate that the safe exposure time for workers is 42.55 hours at point

14 and 81.26 hours at point 15. These values are considered safe, as workers only operate for 8 hours per day.

Table 2. Measurement Results and Classification of Noise Level at Each Point

Noise Level (dB)	Measurement Point	Result
-	27, 28, 30, 35, 37, 38	The point is located above the water filter tank. Therefore, measurements could not be conducted at this point.
< 61	33, 34	The point represents the location with the lowest noise level in the study area. This is because it is the furthest from the noise source and is situated in the southwesternmost part of the layout. Additionally, the presence of numerous walls and plants at this point serves to block and reduce the noise.
61,1 – 66	1, 2, 15, 16, 17, 31, 32, 40	These points are located far from the noise source and are primarily situated in the western part of the layout, whereas point 40 is positioned in the southeasternmost part of the layout. At point 15, measurements were taken inside an office room; however, the room was rarely closed, which may have influenced the recorded noise levels.
66,1 – 71	4, 5, 6, 7, 8, 14, 18, 24, 26, 29, 30, 36, 39	These points are located relatively far from the noise source, except for points 4, 5, 6, 7, and 8, which are closer to the noise source. However, the presence of walls in these areas helps to reduce the sound. Measurements at point 14 were taken inside the operator's room, where the door is rarely closed, potentially affecting the noise levels recorded. The remaining points are situated in the western to southern parts of the layout.
71,1 - 76	3, 9, 19, 23	These points are located in close proximity to the noise source, which may result in higher noise levels compared to other points.
76,1 – 81	10, 11, 20, 21, 22	The point is located near the water pumping machine, which is also in close proximity to the production machines. This positioning may contribute to higher noise levels at this point due to the combined effect of multiple noise sources.
81,1 – 86	12	These points are located around the water pump machine, which is approximately 1 meter away from the production machines. This close proximity to both the water pump and production machines may result in elevated noise levels at these points due to the combined impact of multiple noise sources.
> 86	13	This point exhibited the highest noise level, reaching 86 dB, due to its proximity to the water pumping machine. This noise level significantly exceeded the permissible exposure limit, posing a potential risk of hearing loss to workers in the vicinity

For points that exceed the quality standard threshold, such as point 13 with a noise level of 86.5 dB, the NIOSH-recommended exposure time for workers is:

$$T13 = \frac{480}{2^{(L-85)/3}} = \frac{480}{2^{(86.5-85)/3}}$$
$$T14 = 339\ minutes = 565\ hours$$

At point 13, the noise exposure experienced by workers is approximately 339 minutes or 5.65 hours. Without the use of personal protective equipment (PPE) or noise reduction measures, this level of exposure could negatively impact workers' health. Point 13 is located near the water pump machine, which contributes to the high noise levels. Given this exposure time, additional control measures are required. Without intervention, workers face an increased risk of occupational diseases, particularly hearing loss, in both the short and long term.

Noise Control Solutions

Noise control efforts focus on three main elements: the noise source, the noise transmission path, and the noise receiver. These elements are interconnected, making it essential to understand them before attempting to address the noise problem. In accordance with Regulation Permenaker No. 5 of 2018, it is necessary to apply a control hierarchy to effectively manage noise-related risks.

Addressing the noise source involves implementing engineering controls, such as replacing equipment or components with alternatives that produce lower noise levels acceptable to workers. To control noise transmission, sound-absorbing materials can be installed on the walls of the work area (Amran et al., 2021; Khair, 2021). Additionally, expanding the water treatment plant area and relocating the office to a quieter location may further reduce workers' exposure to noise (Lubis, 2022).

Conclusion

Based on the field measurement results, seven points require noise monitoring. These seven points are located around the water pump 1 (P1) and water pump 2 (P2) machines. with the highest noise level exceeding the threshold set by Permenaker Regulation No. 5 of 2018 and the noise quality standard specified in Minister of Manpower and Transmigration Regulation No. Per.13/Men/X/2011. The highest noise level was recorded at point 13, with a value of 86.5 dB. Therefore, the use of earplugs is essential as a control measure, especially since observations revealed that workers in the dosing system house area rarely use earplugs. According to the noise level measurements at each point, the recommended exposure time calculated using the NIOSH method varies based on the recorded noise levels. For point 13, with the highest noise value of 86.5 dB, the NIOSH-recommended exposure time is 339 minutes or 5.65 hours. This point is located next to the water pump machine, which explains the elevated noise level. Control efforts should prioritize administrative controls and the provision of personal protective equipment (PPE), particularly earplugs or earmuffs, to protect workers from excessive noise exposure. Raising workers' awareness of the risks associated with noise exposure is essential. This can be achieved through training and reminders, as well as ensuring the availability and accessibility of earplugs or earmuffs. These measures aim to prevent occupational diseases, especially hearing loss, which could affect workers in the short and long term.

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Author Contributions

The researchers involved were RF, AC, IY. Conceptualization, RF, AC, IY; data curation, RF; formal analysis, RF, AC; investigation, RF; resources, IY; methodology, RF, AC; project administration, RF; resources, RF, IY; software, RF, AC; validation, AC, IY; visualization, RF; supervision, RF, AC, IY; writing-early drafts, RF; writing-reviewing and editing, RF.

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Conflicts of Interest

The authors declare no conflict of interest.

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