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The Influence of Variations in Cotton, Denim, and Linen Fabrics on Noise Reduction: A Study on Industrial Applications

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ABSTRACT

Noise is a form of environmental pollution that is receiving increasing attention due to its negative impact on human health and quality of life, so it is essential to understand and manage its risks. Based on the observations of the work environment in the P.T. washing room. X Cimahi, which comes from the Steamer Drying Engine, initial measurements for 10 minutes showed that the noise level in the room was above the threshold value at 89.1 dBA, so efforts were needed to reduce the noise level. This research discusses the influence of different types of barrier patchwork media on reducing noise levels. The research carried out was experimental with quantitative experimental methods and a pre-test – post-test research design to find the effect of specific treatments on other variables under controlled conditions in such a way. Sampling in this research was carried out in May 2023 for six days with a measurement time of 10 minutes during productive hours in each work shift to obtain noise level measurements 36 times. This research obtained pre-test results from each of the three treatments in the 88.5-90.5 dBA range. Meanwhile, post-test results from the three treatments obtained an average reduction percentage of 22.6% for cotton patchwork, 17.0% was obtained from denim patchwork, and 12.4% from linen patchwork. The noise level after installing the noise barrier on patchwork media with a thickness of 8 cm on a variety of cotton patchwork media materials, denim patchwork, and linen patchwork can reduce the noise level by 20.2-21.0 dBA, 15.1-15.6 dBA, and 10.9-11.4 dBA. With the significant reduction in noise levels, this patchwork noise barrier can be used as an alternative for noise control.

Keywords: Barrier, Noise, Patchwork

INTRODUCTION

Air pollution refers to the presence of substances in the atmosphere, whether intentional or accidental, that can pose a threat to the health of living organisms. Noise is a form of disturbance in the work environment that requires engineering interventions (Nasution, 2019). The Ministry of Health Regulation No. MENKES/70/2016 on the Standards and Requirements for Industrial Work Environment Health states that the Noise Threshold Limit Value (TLV) regulates the maximum noise exposure for workers. The TLV for noise in this regulation for an 8-hour shift per day or a maximum of 40 hours per week is set at 85 dBA (Health, 2016).

Workplace noise can become a significant occupational hazard when it is perceived as disruptive and serves as a pollutant to the environment (Pal, Taywade, Pal, & Sethi, 2022). Noise issues can cause health problems for workers, such as hearing impairment and disruptions in concentration and emotional well-being, which may eventually lead to increased workplace accidents (Hu & Tkebuchava, 2019). Research by Sari in 2022 indicated that noise levels could also affect blood pressure, leading to serious health conditions and ultimately decreasing productivity (Sari, Demes Nurmayanti, & Faizatul Ummah, 2022).

Certain jobs require workers to be exposed to noise, such as machine operators in the mining industry or other heavy-duty activities (Khaliwa, Magdalena, Iqbal, Susanto, & Ziarahman, 2023). Noise in work environments, such as those found in the washing area of PT. X Cimahi, has the potential to cause serious health impacts on workers and affect work quality. Noise levels exceeding the Threshold Limit Value (TLV) can lead to hearing impairment, increased stress, and reduced concentration, all of which contribute to decreased productivity and workplace safety (Tarnowska, Ras, & Jastreboff, 2017).

Given these negative impacts, it is essential to implement effective noise control measures. This research is crucial to ensure that workers are not only working in safe conditions but are also protected from long-term risks that could impact their health.

However, given the impact of such disturbances, industries should take steps to control noise. Noise control can be achieved through administrative or technical

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means, involving the noise source, transmission path, and noise receiver (Hubbard, 2020). One technical approach to noise control is creating soundproof barriers or partitions made from fibrous and porous materials. These materials can include mineral fibers, rockwool, glass wool, wood fibers, carpets, fabrics, and more.

A study by Irmawati in 2015 found that coconut fiber materials with a thickness of 2 cm were the most effective in reducing noise levels, with an intensity reduction of 20.4 dBA. This was followed by patchwork fabric, which resulted in a reduction of 19.1 dBA, and foam, which provided a reduction of 17.6 dBA (Irmawati, Huboyo, & Sumiyati, 2015). A study by Noviandri in 2016 showed that a 2 cm thick patchwork fabric could serve as a sound barrier, reducing noise by 6-15 dBA (Noviandri & Harjani, 2016).

Another study by Natalia in 2022 revealed that the effectiveness of noise-reducing materials such as coconut fibers, patchwork fabric, and foam varied. The research showed that patchwork fabric had the highest noise reduction, with a decrease of 5.2 dBA, compared to coconut fibers and foam, which reduced noise by 2.3 dBA and 2.1 dBA, respectively (Natalia, 2022).

The study by Natalia also identified a relationship between the type of noise-damping material and its density. The densities of patchwork fabric, coconut fiber, and foam were 0.16875 g/mL, 0.06875 g/mL, and 0.04375 g/mL, respectively (Natalia, 2022). It was explained that materials with higher density are more effective in reducing noise levels.

In addition to density, the porosity of the noise-damping material is an important factor to consider when selecting materials. The denser the material, the smaller its pores, making it harder for sound waves to travel through the air pockets (Tao, Ren, Zhang, & Peijs, 2021). Research by Shiokawa in 2018 showed that patchwork fabric could be used as an effective medium for soundproofing due to its fibers that reduce noise (Shiokawa, Cheng, Noble, & Krolik, 2018). However, the type of patchwork fabric selected must meet the criteria of density, porosity, and fiber composition to effectively dampen sound.

This is to determine whether the selected type of patchwork fabric is capable of effectively absorbing and reducing the existing noise levels. Observations and assessments in the washing area of PT. X Cimahi, where noise from the Steamer Drying Engine was found to exceed the TLV at 89.1 dBA, revealed that workers frequently complained of dizziness due to prolonged exposure to the noise.

The noise levels in the washing area do not comply with the applicable environmental regulations, which set the noise threshold at 85 dBA for an 8-hour workday. Therefore, noise control measures must be implemented to reduce noise levels. The noise control method used in this study involves technical measures, such as creating noise barriers from compact patchwork fabric materials with a thickness of 8 cm, using three different types of patchwork fabric: cotton, denim, and linen.

Moreover, the three materials will be compared to determine which type of patchwork fabric provides the most effective noise reduction. The research on noise reduction levels at PT. X Cimahi from the Steamer Drying Engine, using noise barriers made from different types of patchwork fabric, aims to assess the noise levels at PT. X Cimahi and the resulting reduction and percentage differences in noise reduction from the various types of patchwork fabric used in the study.

RESEARCH METHOD

This research is an experimental study with a quantitative experimental method aimed at understanding the differences in the effects of each type of patchwork fabric on noise absorption levels in the Steamer Drying Engine at PT. X Cimahi, conducted during May 2023 over a period of 6 days. The experimental design used in this study is a pre-test and post-test design to evaluate the effect of noise reduction before and after treatment.

The samples for this study were taken from the overall noise levels at PT. X Cimahi, particularly from the noise generated by the Steamer Drying Engine in the washing room at PT. X Cimahi. The number of samples was determined using the Gomes formula, and the samples obtained were analyzed both univariately and bivariately, along with a One Way ANOVA test. Sampling was carried out over 6 consecutive days for 10-minute intervals during the productive work hours of each shift, specifically at 10:00–10:10 AM, 2:30–2:40 PM, and 6:30–6:40 PM, to collect 120 noise level data points, recorded every 5 seconds during the 10-minute measurement period.

The sample measurements included 18 pre-test measurements for 3 treatments and 6 repetitions, as well as 18 post-test measurements for 3 treatments and 6 repetitions. The noise barrier used in this study had dimensions of Length × Width × Height, with a size of 105 cm × 150 cm × 60 cm and a 8 cm thick plate barrier.

The frame of the noise barrier was made from hollow steel and 2.5mm thick wire mesh plates, shaped to fit the Steamer Drying Engine and designed to resemble a table with an 8 cm thick empty space on all three sides. The design of the noise barrier used in this study is as follows:

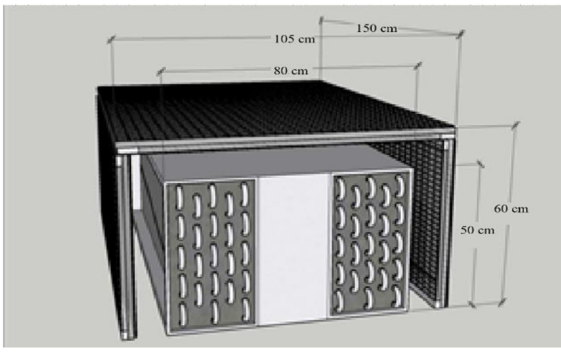

Figure 1. Design View of the Steamer Drying Engine Barrier

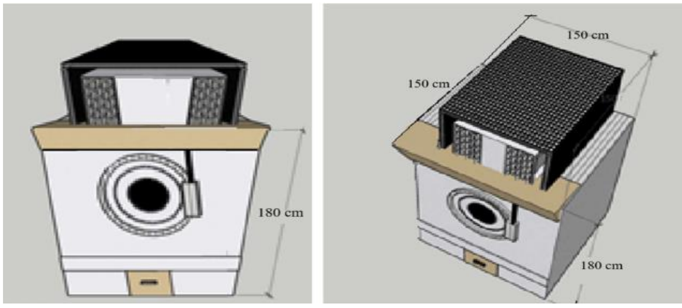

Figure 2. Front and Top View of the Barrier Installation on the Steamer Drying Engine

The empty space with a thickness of 8 cm in the barrier frame is then filled with compacted patchwork fabric, which has been cut and shaped to a thickness of 8 cm for each piece. These pieces are inserted into the barrier space until they are tightly packed and evenly distributed without any gaps.

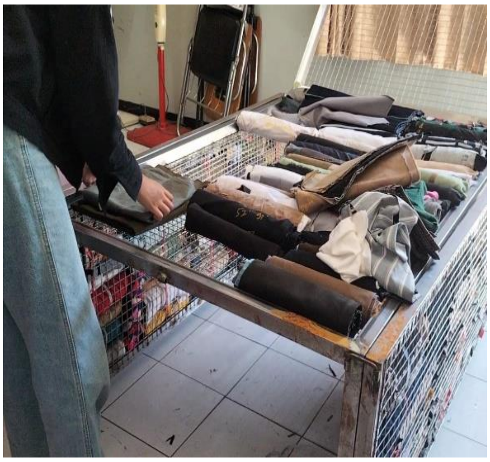

Figure 3. Installation of Compacted Patchwork Fabric in the Barrier

RESULTS AND DISCUSSION

Based on Table 1, the noise level measurements after the installation of the noise barrier with variations in patchwork fabric material showed that the cotton patchwork fabric reduced the noise level from 89.6-90.5 dBA to 69.4-69.8 dBA. The denim patchwork fabric reduced the noise level from 88.7-90.3 dBA to 73.6-74.9 dBA, while the linen patchwork fabric reduced the noise level from 88.5-90.0 dBA to 77.4-78.8 dBA.

The highest noise reduction after the barrier installation occurred with the cotton patchwork fabric, which reduced the noise level by 20.2-21.0 dBA, with a percentage reduction in noise level of 22.3-23.0%.

The data obtained was then analyzed using the One Way ANOVA statistical test with the IBM SPSS Statistics 26 software to determine the distribution of data values, including the minimum value, maximum value, and average value. Below are the results of the data distribution analysis in this study.

Table 1
Noise Level Measurements Before and After Treatment

Replication	Noise Level Before and After Treatment (Patchwork Fabric Variations)											
	Cotton Patchwork Fabric				Denim Patchwork Fabric				Linen Patchwork Fabric			
	P1	P2	S	%	P1	P2	S	%	P1	P2	S	%
1	89.8	69.5	20.3	22.5	89.0	73.8	15.2	17.0	88.5	77.4	11.1	12.5
2	89.6	69.4	20.2	22.5	88.7	73.6	15.1	17.0	89.0	77.8	11.2	12.5
3	89.8	69.6	20.2	22.3	89.1	73.9	15.2	17.0	89.4	78.0	11.4	12.7
4	90.1	69.8	20.3	22.5	89.5	74.1	15.4	17.1	89.6	78.2	11.4	12.7
5	90.3	69.7	20.6	22.8	89.8	74.2	15.6	17.3	90.0	78.8	11.2	12.4
6	90.5	69.5	21.0	23.0	90.3	74.9	15.4	17.0	89.7	78.8	10.9	12.1
Min.	89.6	69.4	20.2	22.3	88.7	73.6	15.1	17.0	88.5	77.4	10.9	12.1
Max.	90.5	69.8	21.0	23.0	90.3	74.9	15.6	17.3	88.5	77.4	11.4	12.7

Notes: P1 = Pre Test (dBA)
P2 = Post Test (dBA)
S = Difference (Noise Reduction Result in dBA)
% = Percentage

Based on Table 2, the average noise reduction after the treatment with the cotton patchwork fabric material was 20.4%. The average noise reduction after the treatment with the denim patchwork fabric material was 15%, and the average noise reduction after the treatment with the linen patchwork fabric material was 11.2%.

Additionally, it can be observed that the smallest noise reduction was found with the linen patchwork fabric treatment, which had a reduction of 10.9%, while the largest noise reduction was found with the cotton patchwork fabric treatment, with a reduction of 21.0%. After conducting univariate testing, the next step was to perform a normality test on the data using the Shapiro-Wilk test. Following that, a homogeneity test and One Way ANOVA test were carried out. When the data is normally distributed and has homogeneous variance, the One Way ANOVA test can be performed to determine the differences between the patchwork fabric materials used.

Table 1
Univariate Test Results for Noise Reduction in the Drying Engine

Data	Patchwork Fabric Material Variations	N	Mean	Std, Deviation	Minimum	Maximum
Reduction	Cotton Patchwork Fabric	6	20.4	0.3141	20.2	21.0
	Denim Patchwork Fabric	6	15.3	0.1835	15.1	15.6
	Linen Patchwork Fabric	6	11.2	0.1897	10.9	11.4

Based on Table 3, the results of the one-way ANOVA test for the noise reduction in the drying engine in the washing room at PT. X Cimahi showed that the P-value (Significant) was 0.0001, which is less than 0.05. Therefore, the null hypothesis (Ho) is rejected and the alternative hypothesis (Ha) is accepted, meaning there is a significant difference in the noise reduction results among the variations of the patchwork fabric materials—cotton, denim, and linen—on the drying engine in the washing

Table 2
One-Way ANOVA Test Results for Noise Reduction in the Drying Engine

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	256,763	2	128,382	2287,990	0.000
Within Groups	0,842	15	0,056		
Total	257,605	17			

In Figure 4, the graph shows a comparison of the noise levels before and after treatment using variations of patchwork fabric materials, namely cotton, denim, and linen. The horizontal axis of the graph represents the categories of pre-test and post-test for each material, while the vertical axis shows the noise levels in decibels (dBA). Before the treatment, the noise levels for the three fabric types (cotton, denim, and linen) ranged from 89 to 90 dBA, exceeding the Threshold Limit Value (TLV), which is indicated by the blue horizontal line around 85 dBA.

After treatment, a significant reduction in noise levels occurred, especially with the cotton patchwork fabric, which showed a reduction to below 70 dBA. The denim patchwork fabric also experienced a notable reduction, but not as much as the cotton, with post-test results around 75 dBA. Meanwhile, the linen patchwork fabric showed a lower noise reduction compared to the other two fabrics, with post-test levels around 78-80 dBA.

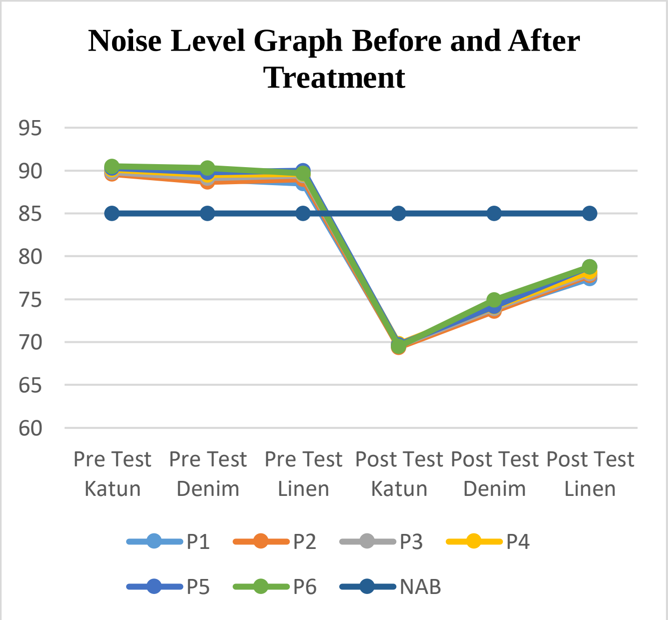

Figure 4. Graph of Noise Levels Before and After Treatment

The garment washing process at PT. X Cimahi uses steam-powered machines, specifically the drying engine, which operates every day in three work shifts. There are approximately 15 workers per shift, working 8 hours per day. Each worker is tasked with washing the garments and may not always be in the drying engine area. However, the noise from the machine affects the surrounding work areas, necessitating noise control measures to maintain a comfortable work environment. The noise in the drying engine area is continuous, operating 24 hours a day.

According to the Minister of Health Regulation No. 70 of 2016, noise is a physical parameter that needs to be controlled if the noise level exceeds 85 dBA for an 8-hour workday. Therefore, the noise from the drying engine must be controlled technically. Noise level measurements taken before the treatment (pre-test) showed the highest noise levels between 90.0-90.5 dBA, which are above the TLV of 85 dBA. After treatment (post-test), using the cotton patchwork fabric, the highest reduction was recorded, with a noise reduction ranging from 20.2 to 21.0 dBA.

The effectiveness of cotton patchwork fabric in noise reduction can be explained by its physical characteristics. Cotton fabric consists of fine and dense natural fibers, which allow this material to have a high sound absorption capacity. The dense fiber structure creates many small cavities that can trap sound waves, reducing the sound energy reflected back into the environment. This differs from materials with looser or stiffer fibers, where sound waves tend to be reflected more than absorbed. The effectiveness of cotton in soundproofing is also supported by its mass and material density (Anam, Pratama, & Lawasi, 2019).

Previous research by Kagitci in 2020 indicated that materials with high density have a greater capacity to reduce sound transmission due to their ability to absorb more acoustic energy. In this context, cotton patchwork fabric has a sufficiently high density to block sound waves and prevent them from traveling to other spaces, significantly reducing noise levels (KAGITCI, 2020). Further supporting research by Santhanam in 2020 also identified that natural fiber-based textiles, such as cotton, have a higher sound absorption coefficient compared to synthetic fibers. They found that adding cotton fabric layers to wall surfaces could reduce noise levels by up to 25%, nearly in line with the results of this study. This is due to cotton's ability to absorb sound waves through a viscoelastic process, where the sound energy is converted into heat energy within the material, reducing the perceived sound intensity (Santhanam, Temesgen, Atalie, & Ashagre, 2019).

Moreover, a study by Cao in 2018 revealed that the microporous structure of cotton fibers plays a crucial role in enhancing its sound absorption capacity. These micropores act as traps for sound waves, forcing the waves to interact with the material for a longer time and reducing their amplitude before they reach the human ear. This phenomenon provides further explanation for why cotton patchwork fabric performs so well in reducing noise in this study (Cao, Fu, Si, Ding, & Yu, 2018).

Overall, the cause-and-effect relationship between the physical structure and fiber characteristics of cotton patchwork fabric and its effectiveness in reducing noise is very clear. The fine, dense fibers of cotton, along with the material's high density, enable it to absorb and dampen sound with high efficiency. These findings align with other research showing that natural fiber-based materials like cotton are highly effective in noise control applications. Thus, using cotton patchwork fabric as an acoustic barrier can be an effective and economical solution for reducing noise in noisy work environments, such as the washing area at PT. X Cimahi.

Denim is a textile material made from cotton fibers, but with a tighter weave and thicker threads compared to regular cotton fabric. The thickness and stiffness of denim provide different acoustic characteristics. Denim has a greater mass compared to thinner fabrics, which helps in reducing sound transmission through physical blocking mechanisms. However, its stiffness also makes it less flexible, reducing the material's ability to effectively absorb sound waves (Hassani, Soltani, Ghane, & Zarrebini, 2021).

Research by Harjani in 2019 showed that materials with tighter weaves, like denim, tend to have better sound-reflecting properties than sound-absorbing ones. This means that most of the sound energy hitting denim's surface is reflected back into the room rather than being absorbed, which reduces its overall effectiveness in noise reduction. This explains why denim patchwork fabric in this study produced a lower noise reduction compared to cotton (Harjani & Noviandri, 2019).

A study by Raj in 2020 also found that textiles with denser and stiffer structures, like denim, have a lower sound absorption coefficient compared to materials with looser and more flexible fibers. The study observed that denim was more effective at reducing low-frequency noise but less efficient at higher frequencies, which are typically more easily absorbed by softer and more porous materials (Raj, Fatima, & Tandon, 2020). This finding is consistent with the results of this study, where denim was able to reduce noise but not as efficiently as cotton, particularly since the dominant sound frequencies in work environments like the washing area at PT. X Cimahi tend to be higher.

Additionally, research by Li in 2020 noted that adding thicker fabric layers, such as denim, could improve the overall sound barrier effectiveness but does not necessarily significantly increase sound absorption. This means that although denim can function as a good physical barrier to prevent sound transmission to other areas, its effectiveness in absorbing sound in the same space is relatively limited (Li et al., 2020). Denim patchwork fabric, while having some potential in noise reduction, is not as effective as cotton in absorbing sound waves.

The cause-and-effect relationship lies in denim's thicker and stiffer physical characteristics, which tend to reflect rather than absorb sound. Nonetheless, denim still contributes significantly to noise control, particularly in contexts where physical barriers are needed to reduce sound transmission. However, for applications requiring high sound absorption, other, more flexible and porous materials may be more suitable (Fu, Zeng, Zhou, Tang, & Liu, 2022). These findings are consistent with previous research that shows that material structure and composition greatly affect its effectiveness in noise control.

Linen is a textile material made from flax fibers, known for its long, strong fibers, but relatively less dense compared to cotton or denim. The natural properties of linen fibers make it lighter and less compact, which negatively affects its ability to absorb sound waves. Linen tends to have a rougher and looser surface, making it easier for sound waves to pass through or reflect rather than being absorbed (Hassan et al., 2021).

Research by Paul, Mishra, and Behera in 2021 indicated that materials with looser and less compact fiber structures tend to have a lower sound absorption coefficient, particularly at high frequencies. Effective sound absorption requires materials with balanced density and porosity, where sound energy can be trapped and converted into heat. However, in the case of linen, the loose fiber structure and suboptimal configuration cause sound waves to not be sufficiently dispersed within the material, leading to a significant amount of sound energy being reflected back into the room (Paul, Mishra, & Behera, 2021).

A study by Sakthivel in 2020 supports these findings, noting that although linen has aesthetic qualities, it is less effective in acoustic applications compared to materials like cotton or wool. The study highlighted that linen shows reduced effectiveness in absorbing sound at mid-to-high frequencies, which are typically the most relevant range for noise control in industrial settings. It was also suggested that linen should be used cautiously as an acoustic material, especially when the goal is to achieve significant noise reduction (Sakthivel, Senthil Kumar, Mekonnen, & Solomon, 2020).

Furthermore, research by Çeven et al. in 2017 found that while linen has good properties for air circulation and moisture management, these factors become weaknesses in noise control applications. The low humidity and high porosity of linen allow sound waves to pass through the material easily without being absorbed, reducing its effectiveness in soundproofing (Çeven & Günaydin, 2018).

Linen patchwork fabric, despite having some advantages in physical properties such as air circulation, is not effective in noise reduction. The cause-and-effect relationship identified in this study shows that the loose and less compact fiber structure of linen contributes to the material's low ability to absorb sound waves. While linen may be suitable for contexts where factors like air circulation or aesthetics are the primary consideration, it is less ideal for applications requiring high noise reduction (WIDYANINGRUM, 2018). These findings align with other studies emphasizing that density, porosity, and fiber structure are key factors in determining noise control effectiveness.

The highest noise reduction achieved with cotton patchwork fabric in this study is influenced by its density, with the density of cotton fabric generally around 0.16875 g/mL and a thread density of 120 × 70/inch. The density value of cotton fabric is higher than that of denim or linen, making it more efficient at reducing noise (Kurniawan & Syamsiyah, 2020).

The denser the fabric, the tighter its pores, making it more difficult for sound waves to pass through the fabric and allowing it to trap sound waves, thus reducing the noise level (Bhat & Messiry, 2020). It is explained that fabric density refers to the compactness of fabric particles, with the density having a direct relationship with the fabric's construction, which includes the number of threads per inch, as well as the warp and weft thread densities (Fauziana, 2019).

There is a direct link between the type of soundproofing material and its density. The densities of cotton patchwork, coconut fiber, and foam are 0.16875 g/mL, 0.06875 g/mL, and 0.04375 g/mL, respectively. It is explained that soundproofing materials with higher density are more effective at reducing noise levels. In addition to density, the tightness of the material is another important factor to consider when choosing soundproofing materials. The tighter the material, the tighter its pores, making it more difficult for sound waves to travel through the air gaps (Niroshan, Madushika, & Niles, 2021).

The results of the noise intensity reduction after the intervention, or the installation of noise barriers using cotton, denim, and linen patchwork fabrics, show significant noise reduction. There is a difference in the effectiveness of each material in reducing noise at the steamer drying engine in the washing area at PT. X Cimahi.

The highest noise reduction was achieved with cotton patchwork fabric. The difference in noise reduction results is attributed to differences in fabric density or fabric tightness. The higher the fabric's density or tightness, the greater the noise reduction achieved.

CONCLUSION

The results of noise level measurements before and after the installation of noise barriers made from patchwork fabric with a thickness of 8 cm at the noise source are as follows: The cotton patchwork fabric variation successfully reduced the initial noise level from 89.6-90.5 dBA to 69.4-69.8 dBA; the denim patchwork fabric variation successfully reduced the initial noise level from 88.7-90.3 dBA to 73.6-74.9 dBA; and the linen patchwork fabric variation successfully reduced the initial noise level from 88.5-90.0 dBA to 77.4-78.8 dBA.

The percentage of noise reduction at the noise source achieved by cotton patchwork fabric was 22.6%, denim patchwork fabric 17.0%, and linen patchwork fabric 12.4%. The most effective noise reduction was found with the cotton patchwork fabric variation, with an average reduction percentage of 22.6%. The ANOVA test results showed a P Value (significant) of 0.001 > 0.05, indicating that there is a significant difference in the noise reduction results between the cotton, denim, and linen patchwork fabric material variations.

SUGGESTIONS

Based on the results of this study, PT. X Cimahi is advised to utilize cotton patchwork fabric as the main acoustic barrier in the washing area, considering its high effectiveness in reducing noise. The installation of this barrier can be carried out around the Steamer Drying Engine and along the sound transmission paths to minimize noise spread. Additionally, the company can consider using denim patchwork fabric as a complement to the noise control system, for example, by adding it as an additional layer to the cotton barrier to provide a stronger and more durable structure.

On the other hand, the use of linen patchwork fabric, which has low effectiveness in noise reduction, is more recommended for other purposes that align with the material's characteristics, such as aesthetic purposes or humidity control. Furthermore, the company should also conduct training for employees to raise awareness about the importance of noise control and implement practical measures, including the use of personal protective equipment such as earmuffs, to reduce noise exposure in the workplace. This training is crucial to ensure that employees understand the health risks associated with noise and how to protect themselves effectively.

The implementation of this noise control solution should be followed by regular monitoring and evaluation to ensure its effectiveness, so that the company can continue to maintain a healthy and comfortable working environment.

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