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Preliminary Evaluation of Sound Insulation Capability in Wood-Based Materials Using Realistic Noise Sources under a Simplified Experimental Approach

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Abstract
This study evaluates the sound attenuation capabilities of four wood-based materials under realistic noise conditions. An experimental approach using a simple, non-standardized test method was conducted in a small-scale chamber, where each material was alternately installed as a barrier. Sound sources included motorcycle horns, falling objects, woodworking machines, and music. Sound intensity was measured using a sound level meter, and each treatment was repeated three times. The data were analyzed using Analysis of Variance (ANOVA) followed by Duncan's Multiple Range Test (DMRT) at a 5% significance level. The results showed that all tested materials significantly reduced sound intensity compared to the control ($P < 0.05$), with the average sound intensity value ranging from 74.6 to 89.6 dB. Statistical analysis confirmed significant differences among materials. In conclusion, wood-based materials demonstrate the ability to reduce sound intensity under practical noise conditions, with particle board showing the best performance, and solid wood showing the lowest performance. Although the method used is simple and not based on standardized acoustic testing, the results provide preliminary evidence of the potential of porous wood-based materials as sound-absorbing media.

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INTRODUCTION

Sound is a phenomenon in physics that is often encountered in everyday life. Sound occurs when an object vibrates, producing sound waves that travel through various media, such as air, water, and solids (Hayati et al., 2025). With the development of the times and the increase in human activity, environmental problems in the form of noise are becoming more frequent and have become a form of pollution that can have physical and non-physical effects on humans. Based on previous research, sound waves that can be heard by humans have frequencies ranging from 20 Hz to 20 kHz (Sihotang et al., 2024), with a maximum intensity limit that does not disturb human hearing of 65 dB (Hutabarat & Harianto, 2024). Noise level above 80 dB can cause permanent hearing impairment; meanwhile, prolonged exposure to loud noise at approximately 100 dB can lead to permanent hearing loss (Muslu, 2025). In a hotel room, the noise comfort standard must not exceed 35 dB (Doelle, 1985). Therefore, efforts are needed to reduce these impacts through noise control.

Noise control is an important aspect in building design, especially in spaces that require comfort and acoustic quality, such as classrooms, studios, public facilities, and residential areas (Fahmi & Nuraini, 2025; Mirjaz et al., 2024; Nirwana, 2021). Wood-based materials are one of the most widely used construction materials, especially wall materials, which play a major role in blocking sound transmission from outside and between rooms (Korjakins & Sahmenko, 2025). Amidst the increasing demand for sustainable materials, various wood-based products have become a promising choice because their physical characteristics and anatomical structure support the absorption and blocking of sound waves. These acoustic properties are greatly influenced by factors such as density, porosity, grain direction, and the characteristics of the constituent layers (Istikhomah et al., 2021; Slamet et al., 2023).

Various wood-based materials, such as solid wood, plywood, laminated wood, and particle board, have different internal structures, which affect their respective soundproofing capabilities (Jati et al., 2024). Wood-based products such as plywood and laminated wood have a layered structure that can provide a different sound barrier mechanism from solid wood, which has a homogeneous structure (Nurmadina et al., 2022). Meanwhile, particle board has a high porosity level that can affect its sound absorption and transmission capabilities (Santoso et al., 2024). These differences in characteristics indicate that each material exhibits a different response when tested using various sound sources with varying frequencies and intensities. Therefore, studies on the acoustic characteristics of these materials are crucial to determine their use in construction applications that require specific soundproofing performance.

However, comparative studies assessing the sound attenuation levels of various wood materials have been conducted, but they are generally limited in scope. Previous studies have primarily evaluated materials such as solid wood, plywood, and particle board using standardised acoustic testing methods, typically relying on controlled single-frequencies or narrow-band measurements (Badri et al., 2024; Prida et al., 2023). While these approaches provide consistent and comparable data, they may not fully represent the complexity of real-world acoustic environments. As a result, an important gap remains in understanding how wood-based materials perform when exposed to more realistic sound conditions. Specifically, there is a lack of studies that incorporate diverse and non-standardised sound sources that mimic everyday noise, such as impacts, machinery, and environmental sounds. To address this gap, the present study systematically evaluates and compares the soundproofing capabilities of various wood-based materials, such as solid wood, plywood, laminated wood, and particle board, using several types of sound sources. Therefore, the objective of this study is to experimentally compare the sound attenuation performance of four wood-based materials (solid wood, plywood, laminated wood, and particle board) under realistic sound conditions using multiple sound sources, including falling stones, music, motorcycle horns, and woodworking machine noise. This approach is expected to provide a more practical and preliminary understanding of the acoustic performance of these materials under real-life sound conditions.

METHODS

1. Sound Absorption Testing

This study employed a quantitative experimental method by measuring and comparing the sound attenuation levels of four types of wood-based materials, namely solid wood, plywood, laminated wood, and particle board. All material samples were obtained from commercial stores and tested under controlled laboratory conditions (moisture content of 15-16%). The wood materials were cut into dimensions of 60 cm × 60 cm with a uniform thickness of 15 mm to ensure consistency of the treatment variables before testing.

The tests were conducted using a small-scale enclosed chamber made of cardboard as a simplified test medium (Jati et al., 2024). A control condition (without any wood-based material

covering the chamber) was included to establish baseline sound intensity levels. Each material treatment, including the control, was tested under identical conditions and repeated three times to ensure data reliability and minimize potential systematic bias. Sound intensity was measured using a sound level meter (AMTAST AMF013) placed inside the test chamber. The test chamber was then alternately covered with each material while exposing it to different sound sources. The experimental setup is illustrated in Figure 1.

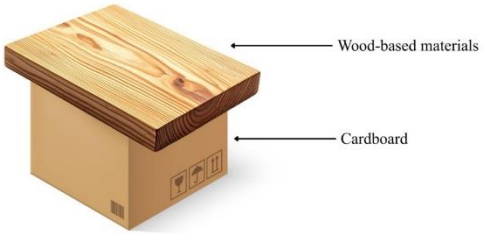


Figure 1. Illustration of the test medium

The sound sources used in this study consisted of motorcycle horns, falling stones (320 g of weight), wood planing machine sounds, and the pop genre of music. The sound sources were placed at the same distance (50 cm) from the test chamber in each test to maintain consistency in the initial sound exposure. Sound intensity measurements were taken by recording the decibel (dB) values recorded on the sound level meter when each sound source was tested. Each test was repeated three times to obtain more consistent results. The data obtained was analysed descriptively and quantitatively by comparing the sound intensity values of each wood material.

2. Data Analysis

In this study, wood-based materials and sound source type acted as the independent variables, while sound intensity in dB acted as the dependent variable. The data were analyzed using Analysis of Variance (ANOVA) with the aid of SPSS software, followed by Duncan's Multiple Range Test (DMRT) at a 5% significance level to determine significant differences among treatments.

RESULTS AND DISCUSSION

In real-world environments, noise is often generated from multiple sources and produces different sound characteristics. For example, motorcycle horns tend to produce sharp and sudden sounds, while woodworking machines generate more continuous noise, and impact sounds such as falling objects create short but intense bursts of sound energy. These variations make real-world noise more complex compared to standardised laboratory sounds (Jorgensen & Wu, 2023; Khan & Burdzik, 2025). However, many standard building materials are typically evaluated under controlled conditions using uniform sound inputs, which may not fully reflect their performance against these varied noise characteristics (Kumar, 2026). As a result, their effectiveness in reducing different types of real-world noise remains less clearly understood.

The use of wood as a sound absorber is ideal for reducing and absorbing sound energy that is usually reflected, and causes echoes in a room (Priyono & Yusdiansyah, 2021). Wood, as a porous material, has a natural fibre and cavity structure that can absorb sound waves (Tiuc et al., 2022). The mechanism of sound absorption in porous materials comes from the presence of interconnected micropores. This structure allows sound waves to penetrate and release energy through heat loss due to friction between air molecules and pore walls, as well as viscosity loss in air flow within the material (Yin & Guan, 2024). Various studies have been conducted to develop porous materials as sound absorbers, including the use of wood-based and composite materials, as they have an internal structure that can increase sound absorption while being environmentally

friendly. The results of these studies show that characteristics such as porosity, density, and thickness of the material greatly affect the effectiveness of sound absorption (Nurhasna & Rauf, 2024; Saputri et al., 2024). For instance, solid wood generally has a more uniform and less porous structure, which may limit the penetration of sound waves and reduce internal energy dissipation (Shi et al., 2024). In contrast, composite materials such as particle board possess a more heterogeneous structure with higher porosity and more complex internal pathways (Rong et al., 2025). This condition increases pore wall interaction and enhances viscous losses, allowing more sound energy to be absorbed (Ren et al., 2023). In addition, the higher tortuosity, or the complexity of the pathways through which sound waves travel within the material, can further improve sound attenuation by prolonging the interaction between sound waves and the internal structure (Ejaz et al., 2025).

Based on these characteristics of porous materials, wood-based materials have the potential to be used as sound absorbers. In general, materials with higher porosity and more complex internal structure are expected to exhibit better sound attenuation due to increased energy dissipation through internal friction and viscous losses. Conversely, denser and less porous materials tend to reflect more sound energy, resulting in lower absorption performance (Meng et al., 2023). Therefore, the measurement results in this study are interpreted based on the relationship between the wood-based material's structure and sound attenuation performance. The materials used in this study included solid wood, particle board, laminated wood, and plywood, which were tested against various sound sources. These measurements aimed to compare the sound absorption capabilities of each wood-based material to determine the most effective material as a sound absorber. The average of measurement results is presented in Table 1.

Table 1. The average of sound intensity (dB) for various noise sources across wood-based materials

Wood-based Materials	Sound Intensity (dB)			
	Motorcycle horn	Stone	Music	Woodworking machine
Control	90.6±4.54^{e}	85.2±0.81^{d}	85.7±0.90^{d}	92.4±0.49^{e}
Solid wood	85.5±1.49^{d}	83.1±0.78^{cd}	80.8±6.18^{bc}	89.2±0.68^{e}
Particle board	81.9±1.34^{cd}	81±1.16^{bc}	77.9±1.72^{ab}	89.2±0.12^{e}
Laminated wood	84±0.56^{cd}	84.3±1.35^{cd}	74.6±1.00^{a}	89.6±0.23^{e}
Plywood	83±2.17^{cd}	83.8±1.01^{cd}	76.1±0.90^{a}	89.3±0.70^{e}

Note: Different letters indicate significant differences (DMRT, P < 0.05).

The sound intensity shown in Table 1 shows clear differences in sound intensity levels influenced by the type of sound-absorbing material used. The analysis of variance (ANOVA) showed that the type of material and sound source had a significant effect on sound intensity ($P < 0.05$). The interaction between factors was also significant, indicating that the effectiveness of each material depended on the type of sound. Further analysis using Duncan's Multiple Range Test (DMRT) at the 5% significance level also revealed significant differences among materials.

In general, sound intensity control conditions consistently produced the highest sound intensity across all sound sources, with values of approximately 90.6 dB (motorcycle horn), 85.2 dB (stone), 85.7 dB (music), and 92.4 dB (woodworking machine). In contrast, the application of wood-based materials reduced sound intensity to varying degrees. For instance, particle board showed lower sound intensity values of around 81.9 dB (motorcycle horn), 81 dB (stone), 77.9 dB (music), and 89.2 dB (woodworking machine), indicating better sound attenuation compared to other materials. Similarly, plywood and laminated wood also reduced sound intensity levels, although not as effectively as particle board in most cases. Solid wood exhibited relatively higher intensity values among the tested materials, such as 85.5 dB (motorcycle horn), 83.1 dB (stone), 80.8 dB (music), and 89.2 dB (woodworking machine), suggesting lower sound absorption capability. These results confirm that without soundproofing materials, sound waves can

propagate freely without significant absorption or reflection (Erbe & Thomas, 2021). Conversely, the use of wood-based materials contributes to noise level reduction, although their effectiveness varies depending on their structural properties (Priyono & Yusdiansyah, 2021).

Among the sound-absorbing materials used, solid wood tends to produce the highest sound intensity compared to other materials. This shows that solid wood has the lowest sound absorption capacity among the sound-absorbing materials tested. This behavior is associated with its dense and relatively homogeneous structure, which limits the penetration of sound waves and promotes reflection and transmission of sound energy (Bucur, 2023; Jang & Kang, 2021). As a result, a significant portion of the sound energy remains unattenuated when passing through solid wood. This phenomenon may be related to differences in acoustic impedance between solid wood and air, which tend to increase sound reflection at the material surface (Mohammadi et al., 2025). In contrast, particle board, laminated wood, and plywood demonstrated better attenuation performance. These composite materials have more heterogeneous structures and higher porosity due to the presence of particles, layers, and adhesive interfaces (Rahmadhani et al., 2025). Such characteristics are likely to enhance energy dissipation mechanisms, including internal friction and scattering within the material matrix, resulting in lower transmitted sound intensity (Setiawan et al., 2024). When sound waves propagate through these materials, they encounter multiple boundaries between wood elements and adhesive layers, causing repeated scattering and reflection at the microstructural level (Fu et al., 2021). Additionally, these materials exhibit higher tortuosity, meaning that sound waves must travel through more complex and irregular pathways within the material. This extended and indirect path increases the interaction between sound waves and the internal structure, thereby amplifying frictional and viscous losses. As a result, more sound energy is converted into heat, leading to lower measured sound intensity (Segura-Alcaraz et al., 2021).

Although this study did not measure frequency-dependent behavior, acoustic impedance, or detailed energy dissipation mechanisms, the observed trends are consistent with general acoustic principles, where porous and composite materials tend to provide better sound absorption than dense and homogeneous materials. For high-intensity sound sources such as machinery noise, the difference in sound absorption values among materials is relatively small, but solid wood still shows the highest sound intensity value. This indicates that for strong and continuous sounds, the sound absorption effectiveness of high-density materials such as solid wood is still limited compared to composite wood (Defrizal & Elvaswer, 2021).

Previous studies have reported varying levels of sound attenuation in wood-based materials. For example, solid wood was reported to reduce sound intensity by around 29 dB (Nering et al., 2019), whereas plywood was successful in reducing noise on ship decks by up to 12 dB (Pasaribu, 2025). On the other hand, Bao et al. (2025) also stated that noise reduction by laminated wood is recorded at 21-27 dB, while particle board is reported to reduce 25 dB (Ferrandez-villena et al., 2022). Compared to these findings, the results of the present study show relatively lower attenuation values. This discrepancy can be attributed to several factors, particularly differences in material thickness and testing conditions. In this study, all materials were tested at a uniform thickness of 15 mm, whereas previous studies often used thicker materials or multilayer configurations, which are known to enhance sound attenuation by increasing the path length of sound propagation and energy dissipation within the material. In addition, the simplified experimental conditions with varied real-world sound sources without frequency control likely contributed to lower measured attenuation values due to the more complex and less predictable sound characteristics.

Despite these differences in magnitude, the overall trend observed in this study is consistent with previous research, where particle board and other composite materials exhibit better sound attenuation performance than solid wood. Particle board demonstrated the most consistent sound attenuation across different noise sources, as indicated by the lowest transmitted

sound intensity values. Although laminated wood performed slightly better for music, particle board remained the most effective material overall. The reduction in sound intensity indicates that part of the acoustic energy is absorbed within the material structure (Kurniawan & Syamsiyah, 2020). Therefore, despite differences in experimental conditions, the present findings support previous studies that highlight the effectiveness of particle board as a sound insulation material. These results reinforce the importance of internal structural complexity and porosity in enhancing sound attenuation performance under practical conditions.

CONCLUSION

Based on the results of the study, all tested wood-based materials significantly reduced sound intensity compared to the control. The sound intensity values produced after the application of wood-based materials ranged from 74.6 to 89.6 dB. Among the materials, particle board showed the most consistent sound attenuation performance across different noise sources, while solid wood generally produced higher sound intensity values, indicating lower absorption capacity. These findings suggest that porous and composite wood-based materials, particularly particle board, have strong potential for application in building acoustics as cost-effective sound insulation materials under realistic noise conditions. However, this study was conducted using a simplified and non-standardized experimental setup and did not consider frequency-dependent behavior. Therefore, further research using standardized acoustic methods is recommended to validate these findings.

SUGGESTION

Further research is recommended using standardized acoustic testing methods (e.g., ISO standards) to obtain more reliable and comparable results. Future studies should include frequency spectrum testing to evaluate frequency-dependent sound absorption behavior, as well as investigate the effect of varying material thicknesses and densities on acoustic performance. Such approaches would provide a more comprehensive understanding of the sound insulation properties of wood-based materials.

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