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# Development of Sound-Absorbing Composites Made from Water Hyacinth Waste and Recycled Cardboard

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**Abstract**

Noise is a factor that can disrupt the comfort and effectiveness of daily activities, including learning. To address this issue, this study develops an environmentally friendly sound-absorbing material made from water hyacinth and cardboard, both of which possess natural porosity suitable for acoustic applications. This experimental research aims to determine the sound absorption coefficient of composite materials produced from various combinations of these wastes. Five composite variations were prepared: Sample A (4 g water hyacinth, 4 g cardboard, 8 g matrix), Sample B (5 g water hyacinth, 3 g cardboard, 8 g matrix), Sample C (3 g water hyacinth, 5 g cardboard, 8 g matrix), Sample D (4 g water hyacinth, 4 g cardboard, 9 g matrix), and Sample E (4 g water hyacinth, 4 g cardboard, 7 g matrix). The absorption coefficient was measured using an impedance tube. The results showed that each composition produced different absorption coefficients. Sample D, with a composite-to-matrix ratio of 7:9, had the highest sound absorption coefficient of 0.327 at a frequency of 100 Hz. Meanwhile, Sample E, with a composite-to-matrix ratio of 9:7, had the lowest coefficient of 0.014 at 350 Hz. The findings indicate that water hyacinth and cardboard can be utilized as sound-absorbing materials, with absorption coefficients ranging from 0.01 to 0.32, thereby meeting the ISO 11654 standard.



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## INTRODUCTION

Noise is generally defined as unwanted sound generated continuously over time, producing discomfort and potentially contributing to adverse health effects (Harfi et al., 2023). From a physical perspective, noise manifests as irregular vibrations that form abnormal acoustic waveforms. Measurements conducted at Universitas Negeri Semarang indicate that ambient noise levels can reach 72.5 dB during weekdays, a value that exceeds the permissible limits established in the Indonesian Ministry of Health Regulation on Noise (No. 718 of 1987). According to this regulation, educational facilities fall under Zone B, where acceptable noise levels range between 45 dB and 55 dB. The elevated noise conditions are largely attributed to various external sources, such as motor vehicle traffic, human conversation, and natural environmental sounds, which collectively disrupt the acoustic environment (Zahrany et al., 2022). Such disturbances negatively affect the quality of classroom learning by impeding verbal communication and decreasing students' concentration. Therefore, the development of environmentally friendly sound-absorbing materials is essential to support a healthier and more conducive educational environment.

The selection of sound-absorbing materials must consider several key parameters, including material composition, density, and fiber characteristics, as these factors directly influence acoustic performance (Nur et al., 2021). Among the various natural fibrous materials, water hyacinth has emerged as a promising candidate due to its structural suitability for sound absorption (Nilahayati et al., 2023). Importantly, water hyacinth possesses a naturally porous and fibrous microstructure, characteristics that align well with the requirements of effective sound-absorbing materials (Privera et al., 2023). These attributes highlight its potential not only as a sustainable alternative to synthetic acoustic materials but also as a value-added solution for managing an abundant environmental waste source.

Sound absorbers derived from water hyacinth generally exhibit lower absorption coefficients compared to other natural fibrous materials, such as banana stem fibers (Harfi et al., 2023; Nilahayati et al., 2023; Zulhiyah et al., 2022). Consequently, transforming water hyacinth waste into an effective acoustic material requires the incorporation of additional components to enhance its sound absorption performance. According to (Wahyudil et al., 2013), a material can be categorized as a good sound absorber when it achieves a minimum absorption coefficient of 0.3. In this context, combining water hyacinth fibers with cardboard offers a promising approach, as the mixture can improve structural porosity and mechanical stability, thereby increasing the material's overall acoustic effectiveness.

On the other hand, cardboard is a porous waste material widely produced as industrial packaging, with its availability increasing in parallel with human activity. Its naturally porous structure enables cardboard to function effectively as a sound absorber (Ritonga et al., 2022). Previous studies have demonstrated its potential; for example, acoustic panels made from cardboard installed in lecture rooms achieved a sound absorption coefficient of 0.531 when measured using a Sound Level Meter supported by noise-logger software (Alvionita et al., 2023). Cardboard-based acoustic components also offer several practical advantages, including low cost, water resistance, and user safety, although they remain vulnerable to physical degradation and misuse (Wardhani et al., 2019). Further evidence shows that increasing the thickness of cardboard composite boards enhances their acoustic performance, with absorption rates reaching up to 16.05% at a thickness of 3 cm (Aldania & Suparno, 2024).

Therefore, this study employs water hyacinth and cardboard as the primary raw materials for developing sound-absorbing composites. Utilizing these two abundant waste materials is expected not only to enhance acoustic performance but also to support environmental sustainability by reducing the volume of unmanaged water hyacinth and cardboard waste. Through this approach, the resulting composite material has the potential to mitigate two forms of pollution simultaneously, waste accumulation and excessive noise, thereby offering an effective, eco-friendly solution for improving acoustic comfort in educational environments.

## METHOD

The fabrication of the sound-absorbing composite began with drying the water hyacinth and cardboard in an oven to remove residual moisture and ensure dimensional stability. After drying, both materials were cut and processed into fine fibers using a blender. Each fiber mixture was then combined with the matrix according to the designated composition. The matrix used consisted of resin and catalyst, with a total mass of 8 grams (7.84 grams of resin and 0.16 grams of catalyst, equivalent to 2% of the matrix mass). Variations in the mass ratios of water hyacinth, cardboard, and matrix for Samples A–E are shown in Table 1.

Table 1. Mass Ratios of Matrix and Sound-Absorbing Composite Made from Water Hyacinth and Cardboard

| Sample Code | Water Hyacinth (g) | Cardboard (g) | Matrix (g) |
|---|---|---|---|
| A | 4 | 4 | 8 |
| B | 5 | 3 | 8 |
| C | 3 | 5 | 8 |
| D | 4 | 4 | 9 |
| E | 4 | 4 | 7 |

The composite and matrix mixture is placed into a press mold with a diameter of 4.5 cm. It is then compressed using a hot press under a constant pressure applied uniformly to all samples. Each sample is pressed for 15 minutes until dry, allowing the composite to be easily removed from the mold. The resulting samples are prepared with a uniform thickness of approximately ±1.5 cm. Each sample is then tested using the Direct Method with a simple impedance tube, as shown in Figure 2, assisted by a Sound Level Meter (SLM) and a Sound Generator application. The tools required to construct the simple impedance tube include a 50 cm PVC pipe, pipe connectors, tape, a speaker, and a sound level meter.

The sound absorption coefficient is obtained from the sound intensity values measured using the SLM. All composite samples are tested directly using the PVC-based impedance tube, which is designed with two small holes for the Sound Level Meter (SLM), a central opening for placing the sample, and an open end for the Sound Generator. Figure 2 shows the simple impedance tube used to measure the absorption coefficient.

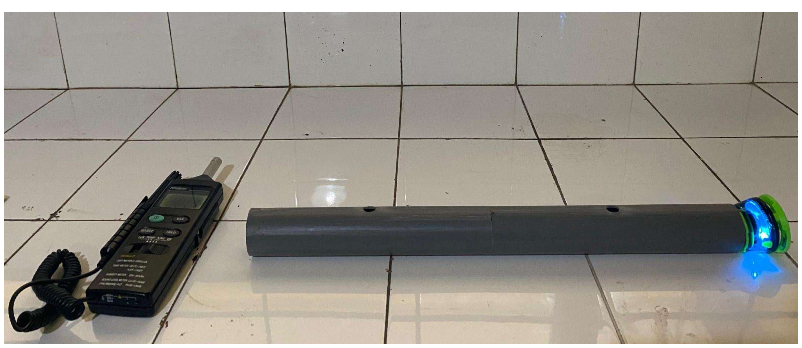

Figure 2. Simple Impedance Tube for Measuring Sound Absorption Coefficient.

The sound absorption coefficient (α) represents the ability of a material to absorb sound. Higher coefficient values indicate greater sound absorption capability. The coefficient ranges from 0 to 1. The sound intensity in the space before the placement of the composite is denoted as $I_0$, while the sound intensity after the composite is placed is denoted as I. After obtaining these values, the absorption coefficient can be calculated using the following formula (Zulhiyah et al., 2022).

$$\alpha = -\frac{1}{x}\ln\frac{I}{I_0} \tag{1}$$

$I$ represents the sound intensity measured in the initial space, while $I_0$ denotes the sound intensity after the composite material is placed. The variable $x$ refers to the thickness of the composite in centimeters, and $\alpha$ is the resulting sound absorption coefficient.

## RESULTS AND DISCUSSION

The sound absorption coefficients were obtained from sound attenuation tests conducted on all variations of the composite sound absorbers. The sound absorption coefficient of a material is strongly influenced by several factors, including density, thickness, and the porosity of the composite's constituent materials. The test results for the sound absorption coefficients of the water hyacinth waste and recycled cardboard sound absorbers for all variations are presented in Table 2.

Table 2. The sound absorption coefficient (α) for the water hyacinth waste and recycled cardboard composite sound absorbers.

| Frequency (Hz) | Sound Absorption Coefficient ($\alpha$) | | | | |
|---|---|---|---|---|---|
| | A | B | C | D | E |
| 50 | 0.250 | 0.184 | 0.218 | 0.220 | 0.249 |
| 100 | 0.323 | 0.243 | 0.322 | 0.327 | 0.311 |
| 150 | 0.169 | 0.130 | 0.204 | 0.217 | 0.203 |
| 200 | 0.067 | 0.048 | 0.077 | 0.119 | 0.104 |
| 250 | 0.097 | 0.098 | 0.133 | 0.131 | 0.131 |
| 300 | 0.055 | 0.039 | 0.061 | 0.040 | 0.062 |
| 350 | 0.015 | 0.018 | 0.028 | 0.018 | 0.014 |

Table 2 presents the sound absorption coefficient values for samples A through E. The sound absorption coefficients of the composite sound absorbers range from 0.01 to 0.32. Sample D, with a composite-to-matrix ratio of 7:9, exhibits the highest sound absorption coefficient, reaching 0.327 at a frequency of 100 Hz. In contrast, Sample E, with a composite-to-matrix ratio of 9:7, shows the lowest absorption coefficient, measuring 0.014 at a frequency of 350 Hz. The most effective sound absorber composition contains a higher proportion of matrix material compared to cardboard and water hyacinth fibers. Sample D also has a denser texture than the other samples. Its higher density indicates a greater material compactness. The denser a sound-absorbing composite is, the greater its sound attenuation capability (Wijayanto et al., 2018).

The collected data were analyzed to determine the relationship between the sound absorption coefficient (α) and frequency for all composite variations. The results show that at a frequency of 50 Hz, Sample A exhibits the highest absorption coefficient. At frequencies of 100, 150, 200, 250, and 350 Hz, Sample D consistently demonstrates the highest absorption performance, while at 300 Hz, Sample E shows the greatest absorption value. A noticeable decrease in absorption occurs at 150 Hz for most samples. The absorption capability of each composite tends to be optimal only at specific frequencies, which is influenced by the irregular distribution of fibers within the composite structure

(Pawestri et al., 2018). These findings indicate that variations in the mass ratio between the composite and the matrix have a significant impact on the resulting acoustic behavior.

Sample D, which contains a matrix mass of 9 g and a composite mass of 7 g, demonstrates consistently higher absorption coefficients across nearly all tested frequencies. In addition to numerical analysis, the samples were also examined based on the surface morphology of their composite structures. Figure 4 presents the physical appearance of Samples A, B, C, D, and E. Visually, Sample D appears denser than the others, with a higher proportion of matrix material that forms a more compact and cohesive structural arrangement. This structural compactness supports the finding that Sample D is the most effective configuration among the tested composite–matrix variations.

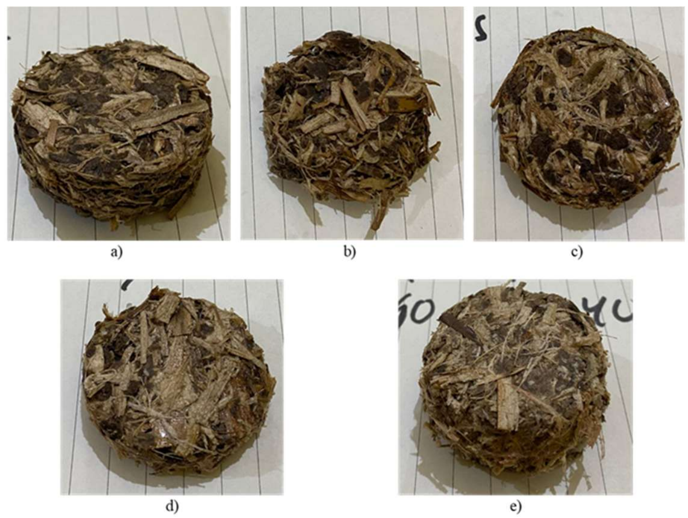


Figure 4. Composite sound absorber samples: (a) Sample A, (b) Sample B, (c) Sample C, (d) Sample D, (e) Sample E.

The sound absorption coefficients of Samples A, C, D, and E reach their highest values at a frequency of 100 Hz, each exceeding 0.3. This experiment was conducted using sound intensities above 80 dB, a level that has the potential to cause hearing damage; therefore, the experiment can be considered compliant with the required testing standards (Zulhiyah et al., 2022). According to ISO 11654, a material is classified as a good sound-absorbing material if it has a minimum sound absorption coefficient of 0.15 (Suherman et al., 2020). Thus, the water hyacinth waste and recycled cardboard composite sound absorber can be effectively utilized as a noise-reducing material.

## CONCLUSION

Based on the results of the study, Sample D with a composite-to-matrix ratio of 7:9, was found to have the highest sound absorption coefficient, reaching 0,327 at a frequency of 100 Hz. In contrast, Sample E, which used a 9:7 ratio of composite to matrix, exhibited the lowest absorption coefficient of 0,014 at a frequency of 350 Hz. These findings indicate that water hyacinth and cardboard can be effectively utilized as sound-absorbing materials, producing composite absorbers with coefficients ranging from 0.01 to 0.32. This range meets the requirements of ISO 11654, demonstrating their potential as environmentally friendly noise-reduction materials.

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