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The Acoustic Material Constructed by the Fiber of *Eichhornia crassipes* and Banana Peel as a Sound Pollutant-reducing Solution

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Abstract

This study aims to evaluate and compare the effect of the composition of water hyacinth (*Eichhornia crassipes*) with a banana peel on the absorption coefficient value as a composite material for absorbing sound waves. The cellulose within the water hyacinth and banana peel lead to reduced overload sound waves. This study used an experimental method providing banana peel crushed into powder, water hyacinth fiber, and resin (as a catalyst). All samples were prepared with dimensions of 13.5 cm × 25 cm × 0.8 cm. A frequency generator application was used as the sound source (125, 250, 500, 1000, and 2000 Hz), while a sound meter application measured sound intensity (dB). The results indicated that the outer surface of sample D had a superior absorption coefficient, measuring 0.51 at 250 Hz and 0.45 at 2000 Hz. Meanwhile, the inner surface of sample D recorded absorption coefficients of 0.46 at 250 Hz and 0.45 at 2000 Hz. Variations in absorption values were attributed to destructive interference and saturation. Sample D contained more water hyacinth (approximately 30%) than banana peel powder. This suggests that water hyacinth and banana peel powder are viable natural fiber alternatives for sound wave absorption.

Keywords: absorption coefficient; banana peel; water hyacinth; sound; cellulose.

INTRODUCTION

Noise pollution can disrupt human activities and affect mental health due to excessive noise. Sound can also trigger psychological disorders in terms of health, such as sleep disorders, hearing disorders, hormonal disorders, increasing the incidence of diabetes, and even heart disease (Safira & Safira, 2017). According to the regulation of the Minister of Health of the Republic of Indonesia No. 718/MENKES/PER/XI/1987, noise is an unwanted sound that causes discomfort to the listener (Kementerian Kesehatan RI, 1987). WHO noted that Europeans have been exposed to excessive noise from road noise as many as 1 in 5 or around 100 million (WHO, 2024). The negative impact of excessive noise is explained by (Wahyudi, 2018) that people in the Cement Industry experience dizziness, headaches, and hearing loss due to a threshold value of 80-85 dB that exceeds the threshold value set for the industry, which is 70 dB.

Threshold Limit Value is the value of disturbance that a person can still accept without causing temporary or permanent hearing loss (below 90 dB). If an individual receives sound more than 90 dB for a long time, it will cause physical disorders in the ear organ (Eryani et al., 2017). Regarding the limit value, each country has different regulations. Japan for residential areas has two limit value determinations, where 45 dB is for the daytime limit and 40 dB at night (Khan & Burdzik, 2023). Unlike Japan, the discovery of the limit value in Europe has three time periods. The limit value in residential areas is around 55 dB during the day. The threshold value in the afternoon is around 50 dB. While at night, the limit value is 45 dB (Khan & Burdzik, 2023).

Currently, several acoustic studies develop sound wave-absorbing materials based on natural fibers. Fibers from hemp, coconut, and abaca have the potency to control noise (Rifaida Eriningsih et al., 2014). Sound-absorbing composites will be characterized by the type of fiber, the physical properties of the fiber, and the morphology. In addition, the absorption coefficient α, ranging from 0 to 1, also determines the absorbed quantity. This value ranges from 0 to 1. If the coefficient value is 1, it depicts that the sound waves are perfectly absorbed 100 percent by the material (Astatika & Dwijaya, 2016). Sound-absorbing materials are indicated by the presence of pores to capture sound waves (Putra & Nazhar, 2020). Water hyacinth and banana peels have pores that can become acoustic materials when processed.

Water hyacinth, Eichhornia crassipes, is a watery plant with massively higher productivity that can disturb the aquatic environment and ecosystem balance. It is not a primary commodity for the community, but it scientifically has natural fiber with a crude protein content of 9.79%, crude fiber of 22.41%, crude fat of 2.82%, ash of 13.32%, and water content of 7.76% (Sihite et al., 2014). Water hyacinth also has a lignin content of 17% (Kusumawati & Haryadi, 2021). On the other hand, banana fruit is widely used by the community, is accessible, and has a low price. The banana peel takes two years to degrade so it will accumulate being waste. It is discovered by fiber content of 17.12%, protein of 9.55%, and crude fat of 4.94% (Fauzana et al., 2012). Banana peel also has a cellulose content of 14.04% and a hemicellulose content of 37.52% (Nasrun et al., 2014). Banana peels and water hyacinth are fabricated as an acoustic material. Therefore, this study will assess the effect of water hyacinth fiber and banana peel composites on the absorption coefficient value of both the outer surface of the material and the inner surface of the material.

MATERIALS AND METHODS

Study area

This study stage includes preparation, fabrication, and testing. The testing limits the measurement of the absorption coefficient to indicate the comparison of materials' capacity.

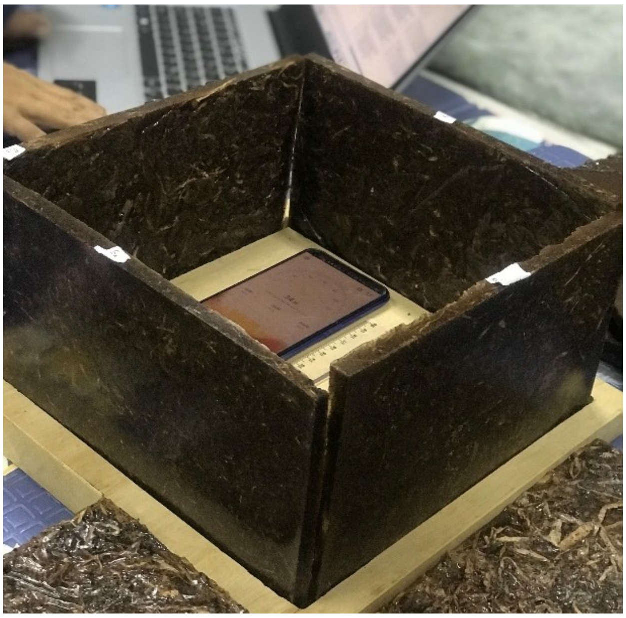

Figure 1. Measurement Design of Acoustic Material. Before measurement, the upper of design should be closed by the material

Procedures

The ingredients contain water hyacinth fiber, banana peel fiber, and polyester resin. The fibers of both materials are exposed to the sunlight. After drying, the water hyacinth fibers are separated and soaked in Sodium Hydroxide (NaOH) and dried again. Meanwhile, the dried banana peel is mashed into powder. Then, all ingredients are divided based on the calculation of variation. There are four variations in the fabrication of acoustic materials, namely (a) sample variation A consists of 60% resin, 40% banana peel, and 0% water hyacinth; (b) sample variation B consists of 60% resin, 30% banana peel, and 10% water hyacinth; (c) sample variation C consists of 60% resin, 20% banana peel, and 20% water hyacinth; and (d) sample variation D consists of 60% resin, 10% banana peel, and 30% water hyacinth. Water hyacinth fiber and banana peel are combined according to the calculation per variation using a mixture of resin and catalyst in a mold. All samples were set in sizes of 13.5 cm x 25 cm x 0.8 cm.

Data analysis

Acoustic material samples will be evaluated on the outside and inside of the material with frequencies of 250, 500, 1000, and 2000 Hz. For the assessment, A smartphone should provide the Frequency Generator application as a sound source generator and the Sound Meter application as a sound intensity meter (Figure 1). The material will be assessed for the absorption coefficient (α). It indicates that the total sound energy can be absorbed by the material. Repetition of calculation is carried out as many as four times. The absorption coefficient value of the material will be obtained from the intensity value equation as follows.

$$I_t = I_i e^{-\propto x}$$

Where:
I_i : The initial intensity of sound wave (W/m^2)
I_t : The transmitted intensity of sound wave (W/m^2)
x : the thickness of material (m)
a : the absorption coefficient of material (m^{-1})

RESULTS AND DISCUSSION

Table 1 and Table 2 are the results of sound intensity and absorption coefficient, respectively. There are differences in the initial intensity value and the transmitted intensity when given a sound source directed at acoustic material with different frequencies. The higher the frequency emitted, the more the absorption coefficient value of each sample tends to increase (Table 2). Sample D has the highest coefficient value of 0.51 at a frequency of 250 Hz and 0.45 at a frequency of 2000 Hz compared to other samples consisting of 60% resin, 10% banana peel, and 30% water hyacinth. The higher the percentage of water hyacinth around 40%, the higher the absorption coefficient value of around 0.343 (Harfi et al., 2023).

Table 1. The comparison between the initial intensity and the transmitted intensity for outside surface material.

Frequency (Hz)	Material							
	I_o (dB)	I (dB)	I_o (dB)	I (dB)	I_o (dB)	I (dB)	I_o (dB)	I (dB)
	A1		A2		A3		A4	
125	63	34	63	27	63	35	63	35
250	71	52	71	46	71	51	71	53
500	87	74	87	71	87	71	87	71
1000	88	73	88	67	88	65	88	68
2000	88	60	88	73	88	73	88	73
	B1		B2		B3		B4	
125	63	41	63	38	63	40	63	36
250	71	54	71	54	71	55	71	52
500	87	73	87	69	87	69	87	68
1000	88	68	88	64	88	66	88	69
2000	88	66	88	64	88	65	88	64
	C1		C2		C3		C4	
125	63	34	63	32	63	27	63	32
250	71	50	71	49	71	51	71	52
500	87	67	87	73	87	70	87	71
1000	88	64	88	66	88	72	88	75
2000	88	71	88	70	88	69	88	67
	D1		D2		D3		D4	
125	63	33	63	28	63	32	63	33
250	71	49	71	45	71	49	71	49
500	87	62	87	66	87	66	87	68
1000	88	67	88	65	88	71	88	68
2000	88	60	88	62	88	64	88	63

Table 2. The absorption coefficient for outside surface material.

Sample	Frequency (Hz)			
	250	500	1000	2000
A	0,40 ± 0,05	0,23 ± 0,05	0,30 ± 0,10	0,31 ± 0,11
B	0,35 ± 0,03	0,28 ± 0,04	0,35 ± 0,04	0,38 ± 0,02
C	0,40 ± 0,05	0,25 ± 0,02	0,28 ± 0,07	0,29 ± 0,05
D	0,51 ± 0,09	0,28 ± 0,04	0,34 ± 0,07	0,45 ± 0,05

Tables 3 and Table 4 explain the results of intensity and the absorption coefficient from the inner surface, respectively. The higher the frequency applied to the same sample, the absorption coefficient value tends to increase. The instability of the absorption coefficient is caused by particles in the acoustic material experiencing saturation and destructive interference (Sinaga et al., 2012). In some frequencies, fluctuations have occurred due to interference from noisy activities in the surrounding environment during the data collection process. The sound meter is also sensitive to the surrounding sound and causes the intensity of the sound read to fluctuate. The highest absorption coefficient with a value of 0.50 is measured in sample D, which consists of 30% water hyacinth, 10% banana peel, and 60% resin. Sample D can be an alternative because its absorption value reaches 0.50 and exceeds the ISO 11654 standard, a minimum absorption coefficient value of 0.15 (Said L et al., 2020).

Table 3. The comparison between the initial intensity and the transmitted intensity for inside surface material.

Frequency (Hz)	Material							
	I_o (dB)	I (dB)	I_o (dB)	I (dB)	I_o (dB)	I (dB)	I_o (dB)	I (dB)
	A1		A2		A3		A4	
125	63	43	63	36	63	34	63	28
250	71	54	71	52	71	51	71	49
500	87	65	87	61	87	68	87	71
1000	88	73	88	71	88	75	88	75
2000	88	62	88	64	88	68	88	63
	B1		B2		B3		B4	
125	63	34	63	37	63	35	63	35
250	71	48	71	51	71	52	71	53
500	87	65	87	67	87	65	87	70
1000	88	68	88	70	88	69	88	68

Frequency (Hz)	Material							
	I_o (dB)	I (dB)	I_o (dB)	I (dB)	I_o (dB)	I (dB)	I_o (dB)	I (dB)
2000	88	63	88	59	88	61	88	64
	C1		C2		C3		C4	
125	63	28	63	32	63	27	63	31
250	71	49	71	53	71	51	71	49
500	87	72	87	69	87	70	87	66
1000	88	73	88	73	88	73	88	73
2000	88	65	88	62	88	64	88	57
	D1		D2		D3		D4	
125	63	31	63	32	63	36	63	32
250	71	51	71	50	71	48	71	50
500	87	62	87	52	87	64	87	64
1000	88	72	88	74	88	74	88	74
2000	88	63	88	62	88	60	88	63

Table 4. The absorption coefficient for inside surface material.

Sample	Frequency (Hz)			
	250	500	1000	2000
A	0,32 ± 0,04	0,34 ± 0,08	0,30 ± 0,04	0,37 ± 0,08
B	0,41 ± 0,05	0,33 ± 0,04	0,31 ± 0,02	0,38 ± 0,05
C	0,40 ± 0,05	0,27 ± 0,06	0,22 ± 0,02	0,42 ± 0,10
D	0,46 ± 0,04	0,48 ± 0,17	0,36 ± 0,03	0,45 ± 0,04

CONCLUSIONS

Natural fibers derived from banana peels and water hyacinth fibers have the potency to absorb sound waves. The absorption coefficient is one of the requirements that indicate the ability of a material to absorb sound waves. The absorption coefficient ranges from 0 to 1. The closer the absorption coefficient value is to 1, the more sound waves are absorbed, resulting in lower sound intensity. From the sample variations, sample D has a higher absorption coefficient compared to other samples. The absorption coefficient for the outer surface of sample D is 0.51 at a frequency of 250 Hz and 0.45 at a frequency of 2000 Hz. Besides, the absorption coefficient for the inside of sample D is 0.46 at a frequency of 250 Hz and 0.45 Hz at a frequency of 2000 Hz. Destructive interference and saturation are some of the causes of instability in absorption values. Thus, sample D is the best sound wave absorbing material compared to other variations with a composition of water hyacinth that is more than a banana peel.

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Competing Interests: The authors declare that there are no competing interests.

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