International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-3, January 2020

Sound Absorption Coefficient of Different Green Materials Polymer on Noise Reduction

Nadiatul Syima Mohd Shahid, Mohamad Ali Ahmad, Farah Liana Md Tahir

Abstract**:** ***One of the sources of noise pollution to environment is from the consumption of electrical and mechanical appliances usage at home and industries. Growth development and advancement of heavy equipment in construction work further emphasize the necessity used of new technologies for noise reduction. The best technique of control or reducing of noise is by using the materials that can absorb the noise by materials itself. Potential materials from agricultural waste as sound absorber were identified. There are two main objectives in this study; First is to produce acoustic absorber by using natural materials. Second is to identify their sound absorption coefficients. The samples were fabricated using the raw materials from banana stem, grass, palm oil leaves and lemongrass mixed with binding agents of polyurethane and hardener to the ratio of 1:4. The diameters of the samples consist of 28mm and 100mm and the thickness is 10mm. The samples sound absorption coefficients were measured according to standards ASTM E1050-98 / ISO 105342-2 (Impedance tube method). Sound absorption coefficient of the materials depends on frequencies choose. The frequencies values used in this study were in the range from 500Hz to 4500Hz. Material made from grass have a higher average sound absorption coefficient value which is 0.553. All tested samples also can be categories under class D type of materials based on sound absorption coefficient value.***

Keywords**:** ***acoustic, natural materials, palm oil leaves, polyurethane.***

I. INTRODUCTION

Demand on the quality of life for a better environment and extra expanded life styles has been improved along with the growth of industrial construction and transportation. Poor urban planning can cause pollution to our society, which becomes one of the four major environmental hazards which are noise, air, water, and solid waste pollutions [1]. However, this process may lead to various problems such as environmental issues and human's health. Noise pollution also gives a bad impact on human's life [2]. According to the World Health Organization (WHO), annoyance and sleep disturbance from noise pollution can contributes to the source of heart disease [3].

Revised Manuscript Received on January 30, 2020.
* Correspondence Author

Nadiatul Syima Mohd Shahid, Faculty of Health Science,Kampus Puncak Alam, 42300 Bandar Puncak Alam, Selangor, Malaysia.

Mohamad Ali Ahmad*, Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.

Farah Liana Md Tahir, Faculty of Mechanical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.

Sound and vibration produced by home appliances, motor vehicles and buildings also contribute to harmful side effects [4]. Quality environment by reducing noise pollution can be achieved by installing noise control barrier. The application of sound absorber has been known as noise control. Normal practices on noise reducer can be categorized as absorption, isolation, vibration isolation and vibration damping. The most important role to reduce noise is the material with sound absorption capability [5]. Materials with the capability of softening the acoustic environment of closed volume are normally fibrous and porous. This material ought to have the best absorptive capability by dropping the amplitude of the reflected waves. However, as reported by Arenas [6], the porous materials sound absorption coefficient tends to be higher. Other parameters affecting properties of sound absorbing are surface finishing, method of installation, material thickness. Material compositions and the frequency of sound also affecting the characteristic of absorptions.

Glass wool, stone wool, and foam plastics derived from synthetic materials are the common acoustic absorbers which can be found in the market [7]. The recent advances of fabricating sound absorber from natural materials have been reviewed by some authors. Nasmi et al. [8] used corn husk fiber (CHF) and unsaturated polyester as the sound-absorbing materials. They found that acoustical and non-acoustical properties of composites influenced by the volume fraction of CHF. High absorption coefficient can be obtained in random pattern of fibers. Lei and Fu-Shen [9] developed waste agricultural plastic film as raw material. This material is suitable for applications such as construction of bridges, installation of internal tunnels during short period road construction and as parts in vehicles. Elammaran et al. [10] studied on characterization of rice straw fibers treated with sodium hydroxide and the results showed that lower fiber content in composites were poorer in sound absorption compared to the composites with higher fiber content which had better sound absorption. Manigandan et al. [11] studied the mechanical and acoustic properties of pineapple leaf fiber and it was proven that the fiber can be used reduce noise. In addition, Jichun et al. [12] looked at the effect of natural materials and sandwich structure composites to the sound absorption characterization. The result showed that natural materials-based sandwich structure can be used as the potential sound absorption structure against high frequency.

On the other hand, acoustical material plays some major roles especially in acoustic construction such as room acoustics control, noise control for industrial, studio and automotive acoustics.

Selection of material is important to minimize unwanted effects of sound reflection. This unwanted effect is due to hard and rigid interior surfaces and thus help to reduce the reverberant noise levels. The materials for sound absorption are applicable as interior lining for apartments, automotive, aircraft, ducts, enclosures for noise equipment and insulations for appliances [13].

The response of creative performance spaces can be controlled through sound absorptive materials in order to firm and transient sound resources. Report show that this material is capable to affect the atmosphere of the audio environment and at the same time improve the intelligibility or unreinforced speech and the quality of unreinforced musical sound [14]. Combining the absorptive materials with barriers can be formed to produce composite products to lag pipe or provide absorptive curtain assemblies. The spectra of the emitting source can control all noise problems. Selection of sound absorbing materials will be based from materials type and dimension while controlling frequency of sound [15]. This paper discovers the sound absorption coefficient of natural fibers from agricultural wastes as potential acoustic absorber.

II. EXPERIMENTAL METHOD

A. Sample Preparation

Four types of material from agricultural waste which are banana stem, lemongrass, palm oil leaves and grass initially underwent a treatment process to obtain strong sample structure. The treatment was also done to obtain the cleanest appearance to the green materials. The materials are collected and cut into 20 mm and 30 mm length respectively. All samples are sundried up to one week to remove any excess moisture content and isolate them from impurity that present in the materials. After that, the samples are heated in oven at 80^{o}C for 12 hours to allow the excess water in the materials evaporated. Another purpose is to ensure the materials stayed clean and strong. The smallest part of dried samples was chopped into 5-10 mm length as shown in Fig. 1 [16].

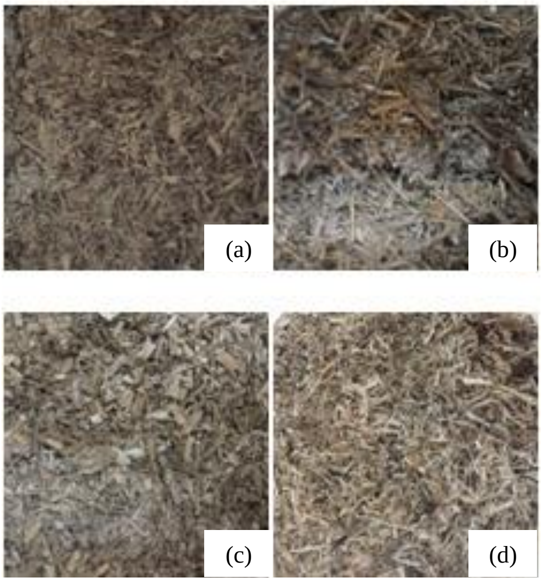

Fig. 1. Samples of (a)Lemongrass, (b)Banana Stem, (c)Palm Oil Leaves and (d)Grass wasted fibres after treatment

The mass of each sample was measured by using electronic weight balance. The binding agent of polyurethane and hardener was mixed with the weight ratios of 1:4. Two plastic molds were used to prepare two different samples of sizes which was equivalent to the diameters of the impedance tube. It covers the low and high frequency range of measurements. The size of the sample is 28 mm and 100 mm on diameter. The value of sample density was measured and recorded. The bulk density calculated by the ratio of the sample mass over the volume of the cylindrical shape [17].

B. Measurement of Sound Absorption Coefficient

Sound absorption coefficient was measured using impedance tube equipment as shown in Fig. 2. The purpose of the testing was to identify the sound absorption coefficient, α for each of samples. From an impedance tube, the measurement of sound absorption coefficient was achieved. American Society for Testing and Material, (ASTM E1050 /ISO 10534-2) standard was consolidate when using two microphone transfer function method for measurement [18]. The absorber sample tested was fitted in the impedance tube. There must be no gap or extreme small gap between the sample and cell wall of impedance tube. White noise signal was fed into the tube generated by a loudspeaker. The loudspeaker was fixed closed to impedance tube end. The loud speaker generates broadband, stationary random sound waves which propagate inside the tube as plane wave, then hit the sample and reflected. Two-channel digital frequency analyzer were used to measuring the sound pressure at two fixed locations and complex transfer function. This data was used to calculate sound absorption coefficient.

Fig. 2. Tube Used for Testing

Tube diameter and the the space between the microphone positions affected the operational frequency range selection. Sound pressure produce inside the tube was recorded by microphones and amplifier below: -

a) Pre-polarized microphones model GRAS 40AE and
b) Pre-amplifier 1/200 CCP model GRAS 26CA

The microphones' sensitivity was calibrated by using calibrator type GRAS 26CA at 114dB level and 1 kHz before the test begin to prevent error. The signal was process with SCS software. The main parameters of four types of samples were tabulated as shown in Table I. The average mass and density were calculated for each diameter of the samples.
The average mass was taken based on three times reading on the electronic balance.

Table - I: Basic Parameters of the Four Samples Used in the Experiment specifications

Material	Diameter (mm)	Thickness (mm)	Average mass (g)	Density (kg/m^3)
Banana Stem	28	10	3.2668	132.635
	100	10	31.4259	100.0188
Grass	28	10	2.5768	104.6204
	100	10	14.9571	47.6038
Lemongrass	28	10	3.0293	122.9923
	100	10	63.1508	200.9892
Palm Oil leaves	28	10	4.729	192.0016
	100	10	47.7469	151.9634

III. RESULTS AND DISCUSSIONS

The absorption coefficient of each sample was tabulated as shown in Table II for the frequency range between 500 Hz to 4500Hz.

Table - II: Sound absorption coefficient of different materials for difference frequency

Frequency (Hz)	Material			
	Banana Stem	Grass	Palm Oil Leaves	Lemongrass
500	0.05282	0.05966	0.04569	0.06323
1000	0.10339	0.14697	0.07852	0.14822
1500	0.19083	0.25352	0.10541	0.26073
2000	0.42014	0.43586	0.18864	0.45459
2500	0.80148	0.65405	0.33111	0.66547
3000	0.99478	0.84027	0.56293	0.82473
3500	0.78405	0.92164	0.89659	0.85822
4000	0.54971	0.89008	0.95232	0.79980
4500	0.41968	0.77944	0.83087	0.71887

From the data obtained, the potential of creating an alternative of sound absorber from agricultural waste can be identified. Sound absorption class can be Classified as tabulated in Table III [19] based on its coefficient value. The best sound absorption class is A with coefficient range 0.90-1.00 followed by B, C, D, E and not classified.

Most of the materials have good sound absorption coefficient especially for the frequency between 2500 Hz to 4500 Hz accept for banana stem material. Different type of green materials influences the sound absorption coefficients. It can be seen from the results that the values for these four types of samples were determined from the resonant frequency of 500Hz to 4500Hz (Fig. 3). These range of frequency has been selected to satisfy the fundamental constraint that had been highlight by ASTM. Based on the standard, the diameter of impedance tube and the spacing between the microphone positions strongly affected the usable range of frequency. It is important to know the limits of the working frequency to maintain the plane wave propagation inside the tube.

Table - III: Sound absorption class [19]

Sound Absorption Class	Absorption Coefficient, α
A	0.90 – 1.00
B	0.80 – 0.85
C	0.60 – 0.75
D	0.30 – 0.55
E	0.15 – 0.25

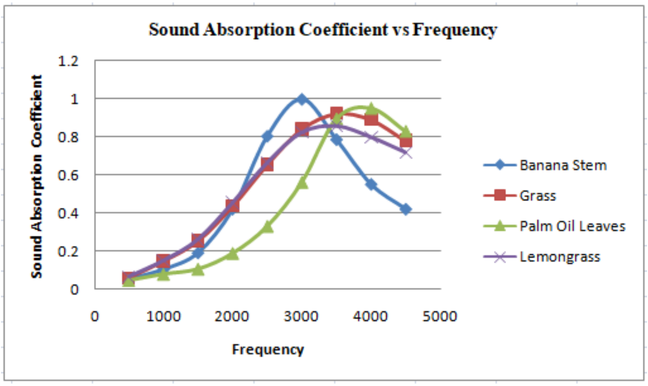

Fig. 3. Sound absorption coefficient of different material at different frequency

As shown in Fig. 3, at the frequency range between 500-3000Hz, absorption coefficient for banana stem increased and reached the maximum coefficient value of 0.995. The sound absorption performance had decreased until the value of 0.42 at 4500Hz frequency. For sample made of grass and lemongrass, the absorption coefficient values showed an increment from frequency 500-4000Hz and dropped after the frequency of 3500Hz. The maximum values of the absorption coefficient are 0.921and 0.858 respectively. For sample made of palm oil leaves, the highest absorption coefficient was 0.952 at 4000Hz before it decreased at 0.831 at a frequency of 4500Hz. All the samples exhibited a similar pattern of sound absorption. The average sound coefficient was calculated and obtained the values of 0.479, 0.553, 0.443 and 0.533 for the banana stem, grass, palm oil leaves, and lemongrass materials respectively. All these values of the absorption coefficient can be classified in absorption class D as shown in Table III.

Measurement of the absorption coefficient values at a different frequency as the method to identify the materials chosen sometimes may not suitable or might be too complex. The alternative approach is to use noise reduction coefficient (NRC).

This method uses a single value calculation by measuring the ability of the materials to absorb sound [20]. The sound absorption coefficient average for materials at different frequency namely 125Hz, 250Hz, 500Hz, 1000Hz and 2000Hz was obtained to calculate the NRC of the fiber's samples. The higher the NRC value indicates ~~as~~ the better ~~of~~ the product in absorbing sound. The NRC can be calculated using the formula [21]:

$$NRC = \frac{\alpha_{250} + \alpha_{500} + \alpha_{1000} + \alpha_{2000}}{4} \quad (1)$$

The comparison between the materials on NRC from the values of the noise reduction coefficient is showed in Fig. 4. The grass composite material has the maximum NRC value of 0.1717 compared to the others. It means that the material absorbed by 17.17%. The banana stem, palm oil leaves, and lemongrass composite materials obtained 0.1524, 0.0859 and 0.1668 NRC values respectively.

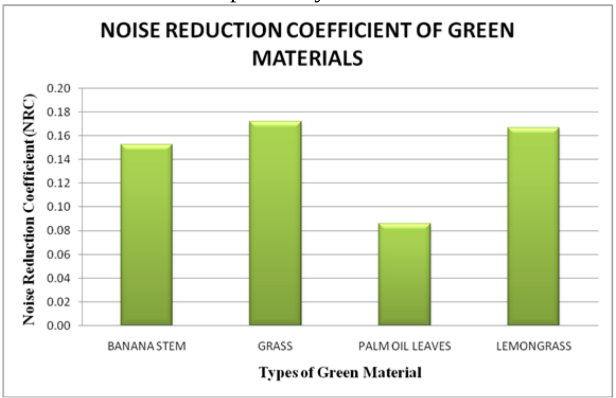

Fig. 4. Noise Reduction Coefficient (NRC) for different materials.

The thickness of absorbent material is one of the main parameters that influence absorption performance. A higher frequency will absorb more sound than low frequency. Hence, the amount of absorption not only depends on the thickness, but the type of materials and the method of installation. Table IV summarized the maximum sound absorption coefficient value of natural fibers that have been done by other international researches internationally.

Table - IV: Sound Absorption Coefficient of Natural Fibers by other researchers [22]

Researcher	Material	Thickness (mm)	SAC	Peak Frequency (Hz)
[23]	Coconut	10	0.46	4000
	Corn		0.70	3000
	Grass		0.46	4000
	Sugarcane		0.88	4000
[24]	Coconut	10	0.39	5000
[15]	Tea-leaf	10	0.26	4000-6300

The value of sound absorption coefficient obtained from selected waste materials show better properties compared to other materials.

IV. CONCLUSION

Sound absorption coefficients of four different types of green material were successfully conducted. A constant thickness sample was considered in this study. The values of sound absorption coefficient lie between the range of 0.046 to 0.831 with the positive gradient from the frequency of 500Hz to 4500Hz. Material made from grass have a higher average sound absorption coefficient value which is 0.553. All the sample tested also can be categorized under class D type of materials based on sound absorption coefficient value. All the materials are natural, renewable and agricultural waste which does not pose harm to human health. By introducing the composite materials from agricultural waste, the resulting materials show good potential to be an environmentally friendly product.

The development of other new materials from agricultural waste is needed for acoustic absorption purposes in the future. The manufacture of these new materials will contribute to environmental protection and sustainable acoustic absorption solutions that are cheaper than the traditional alternatives.

ACKNOWLEDGMENT

The authors would like to thank Universiti Teknologi MARA for the Research University Grant, LESTARI (087/2017), Faculty of Mechanical Engineering, and Malaysia Ministry of Education for their support financially and all anonymous contributing in this work especially for the device and specimens.

REFERENCES

1. H. Qui and Y. Enhui, "Effect of Thickness, Density and Cavity Depth on the Sound Absorption Properties of Wool Boards," Autex Res. J., vol. 18, no. 2, pp. 203–208, 2018.
2. H. Mamtaz, M. H. Fouladi, M. Al-Atabi, and S. N. Namasivayam, "Acoustic absorption of natural fiber composites," J. Eng. (United States), vol. 2016, Art. no. 5836107, 2016.
3. S. Manigandan, P. Gunasekar, S. Nithya, J. Devipriya, W. S. R. Saravanan, and S. Venkatesan, "Acoustic and vibration analysis of pineapple leaf fibre laminates for aircraft applications," Int. J. Ambient Energy, 2018.
4. M. R. G. Ravandi, H. Mardi, A. A. A. Langari, M. Mohammadian, and N. Khanjani, "A Review on the Acoustical Properties of Natural and Synthetic Noise Absorbents," OALib, vol. 2, no. 8, 2015.
5. E. Jayamani, S. Hamdan, and N. B. Suid, "Experimental Determination of Sound Absorption Coefficients of Four Types of Malaysian Wood," Appl. Mech. Mater., vol. 315, pp. 577–581, 2013.
6. Arenas, J. P., & Crocker, M. J. (2010). Recent trends in porous sound-absorbing materials. Sound & vibration, 44(7), 12-18.
7. K. H. Or, A. Putra, and M. Z. Selamat, "Oil palm empty fruit bunch fibres as sustainable acoustic absorber," Appl. Acoust., vol. 119, pp. 9–16, 2017.
8. N. H. Sari, I. N. G. Wardana, Y. S. Irawan, and E. Siswanto, "Corn Husk Fiber-Polyester Composites as Sound Absorber: Nonacoustical and Acoustical Properties," Adv. Acoust. Vib., vol. 2017, Art. no. 4319389, 2017.
9. L. Wang and F. S. Zhang, "Characterization of a novel sound absorption material derived from waste agricultural film," Constr. Build. Mater., vol. 157, pp. 237–243, 2017.
10. E. Jayamani, S. Hamdan, M. R. Rahman, and M. K. Bin Bakri, "Study of sound absorption coefficients and characterization of rice straw stem fibers reinforced polypropylene composites," BioResources, vol. 10, no. 2, pp. 3378–3392, 2015.
11. A. Putra, K. H. Or, M. Z. Selamat, M. J. M. Nor, M. H. Hassan, and I. Prasetiyo, "Sound absorption of extracted pineapple-leaf fibres," Appl. Acoust., vol. 136, no. February, pp. 9–15, 2018.
12. J. Zhang, Y. Shen, B. Jiang, and Y. Li, "Sound Absorption Characterization of Natural Materials and Sandwich Structure Composites," Aerospace, vol. 5, no. 3, p. 75, 2018.

13. Knapen., E., R. Lanoye, G. Vermeir and D. Van Gemert, 2003. “Sound Absorption by Polymer-Modified Porous Cement Mortars”, 6th International Conference on Materials Science and Restoration, MSR-VI Aedificatio Publishers, pp: 347-358.
14. Frank Fahy, 2001. “Foundations of Engineering acoustics”, San Diego, Calif.; London: Academic Press.
15. Francisco Simon and Jaime Pfretzschner. “Guidelines for The Acoustic Design of Absorptive Devices, Noise and Vibration worldwide”, Instituto de Acœstica (CSIC), 2004.
16. Yang, H. S., Kim, D. J., & Kim, H. J. (2003). Rice straw–wood particle composite for sound absorbing wooden construction materials. Bioresource Technology, 86(2), 117-121.
17. Kasolang, S., Ahmad, M. A., Bakar, M. A. A., & Hamid, A. H. A. (2012). Specific wear rate of kenaf epoxy composite and oil palm empty fruit bunch (OPEFB) epoxy composite in dry sliding. Jurnal Teknologi, 58(2).
18. R. Durairaj, T. W. Hong, H. S. H. B. Hamid, S. Amares, and E. Sujatmika, “A Review: Characteristics of Noise Absorption Material,” J. Phys. Conf. Ser., vol. 908, p. 012005, 2017
19. P. A. Tools, D. W. H. Y. Stonewool, C. Us, E. N. Iso, and E. N. Iso, “Sound classi cation,” pp. 1–2, 2019.
20. Yang, W., & Li, Y. (2012). Sound absorption performance of natural fibers and their composites. Science China Technological Sciences, 55(8), 2278-2283.
21. Jansen, M. (2012). Noise reduction by wavelet thresholding (Vol. 161). Springer Science & Business Media.
22. Samsudin, E. M., Ismail, L. H., & Kadir, A. A. (2016). A Review on Physical Factors Influencing Absorption Performance Offibrous Sound Absorption Material from Natural Fibers. Arpn Journal of Engineering and Applied Sciences, 11(6), 3703-3711.
23. Fouladi, M. H., Nassir, M. H., Ghassem, M., Shamel, M., Peng, S. Y., Wen, S. Y. & Nor, M. J. M. (2013). Utilizing Malaysian natural fibers as sound absorber. In Modeling and Measurement Methods for Acoustic Waves and for Acoustic Microdevices. Intechopen.
24. Zulkifli, R., Zulkarnain and Nor, M.J.M. 2010. Noise control using coconut coir fiber sound absorber with porous layer backing and perforated panel. American Journal of Applied Sciences. 7(2), pp. 260-264.

AUTHORS PROFILE

Nadiatul Syima Mohd Shahid, Ph.D obtained her Diploma in Environmental Health and Bachelor Degree with Honest in Environmental Technology from Universiti Teknologi MARA, Malaysia. She was awarded with Master of Science in Food and Consumer Safety from University of Teesside, United Kingdom. She finished her Doctor of Philosophy in Public Health (Food Safety) from Curtin University of Technology, Australia. Start her carrier in August 2008 as lecturer at Faculty of Science Health at Universiti Teknologi Mara.

Mohamad Ali Ahmad is Senior Lecturer Thermofluids and Energy studies centre in the Faculty of Mechanical Engineering, Universiti Teknologi MARA. He has a first degree in Mechanical Engineering from University of Malaya and a PhD in Tribology. After graduating he worked for Omron (M) Sdn Bhd in the Engineering & Machine Development Division and Facility Maintenance. Ali joined the Faculty in 2016; he manages the Ducom-UiTM Tribology Centre for Tribology that specializes in industrial wear and lubrication problems, and the development of metrology tools for tribology. Ali teaches fluid mechanics, engineers in society and tribology of machine elements to undergraduate and postgraduate students.

Farah Liana Md Tahir is undergraduate final year student at Faculty of Mechanical Engineering at Universiti Teknologi MARA, Shah Alam Selangor. This paper part of Final Year Project supervised by Dr Mohamad Ali Ahmd and Dr Nadiatul Syima Mohd Syahid.