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Reducing Noiseđ – The Impact of Biocomposite Noise Dampers with Grinting Grass (*Cynodon dactylon*) on Noise Intensity

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ABSTRACT

The use of machines and technology in the industrial sector has led to noise pollution, which requires attention. The practice of noise control through soundproofing is closely linked to the use of various acoustic materials, whether they are synthetic or natural fibers. Natural materials are preferred for biocomposite reinforcement due to the design flexibility, eco-friendliness, sustainability, and ease of availability. Therefore, this research aimed to analyze the variation of grinting grass (*Cynodon dactylon*) composite material as damper with safe working distance from noise exposure. This experimental research was conducted using industrial grinding machine and damper from grinting grass as the object and composite material. The instruments used for measurement included an Impedance tube (sound absorption coefficient), a sound level meter (noise intensity), and a Surfer 13 noise mapping application. The data obtained were analyzed using the Wilcoxon test to determine the differences before and after the intervention. The results showed that the most effective composite had a 60:40 ratio with a sound absorption coefficient of 0.30. Before using damper, the highest noise intensity recorded was 106 dBA, which was reduced to 83 dBA. Safe working distance from exposure before damper was 6.1 meters, which decreased to 1 meter after the intervention. In conclusion, there was a significant difference in noise intensity ($p = 0.000$) and safe working distance from exposure ($p = 0.001$) before and after the use of grinting grass as damper

Keywords: grinting grass composite, damper, noise intensity, safe working distance.

INTRODUCTION

The progress in technology and industrialization has resulted in the creation of various tools and equipment that are indispensable for meeting human need. These tools include production equipment, transportation, communication, information, and entertainment facilities. However, the consequence of these developments is the emergence of unwanted sound, commonly known as noise (I Made Astika, 2016). This form of environmental disruption affects residential areas, offices, educational institutions, etc., and is a problem that needs to be addressed. Noise control, following the hierarchy of control, can be achieved by providing silencer. Its production requires the use of eco-friendly materials to minimize environmental impact.

The use of silencer material designed to absorb sound is an effective method adopted to minimize noise generated from various sources (Milawarni, 2017). The ideal choice for developing the material, which can also serve as composite filler, is natural fiber (Pratiwi et al., 2017). This preference for natural fiber is based on the inherent ability to reduce sound levels for noise control, which is attributed to its higher porosity and amorphous structure compared to synthetic materials (Mutia et al., 2016). Meanwhile. grinting grass (Cynodon dactylon) contains 9.08% crude protein and 48.17% crude fiber, making it a suitable filler or composite material that can be effectively used as silencer (Marselinus et al., 2020).

Composite is defined as a combination of two or more materials mixed with a natural or synthetic binder (Erwan et al., 2015). The appropriate composition could effectively reduce sound in high-noise environments. Several research focused on the use of composite for this purpose. For instance, Komaruddin (2006) used coconut coir and starch as filler and matrix to produce silencer composite. This type of composite successfully met the requirements of ISO 11654, with a sound absorption coefficient (α) greater than 0.15. Similarly, Farid et al. (2012) explored sugarcane fiber as sustainable acoustic absorber and reported that a 1.25 cm thickness hhadas an average absorption coefficient of 0.65 in the frequency range of 1.2 to 4.5 KHz. Kartikaratri et al. (2012) examined the production of coconut coir fiber and phenol formaldehyde resin composite and stated that the absorption coefficient was 0.94, in the frequency range of 752 to 6400 Hz. Fajri (2015) used bagasse natural fiber as noise control and reported that the highest sound absorption coefficient was observed at 1000 Hz, relatively 0.961. These research collectively stated the benefits of using natural fiber in preparing composite material for noise reduction.

To ensure safe working distances in environments with potential noise exposure, the Minister of Manpower Regulation Number 5 of 2018 set a clear standard. It stipulated that the maximum permissible noise intensity should not exceed 85 dB over 8 hours daily. To adhere to this regulation and promote safety, an exposure mapping tool, the Surfer13 application, was used. This application was represented by color-coded zones, clearly showing safe working areas for 8 hours per day or in the specified time limit. Workers can use ear protection devices to manage noise levels that surpass the permissible limit, although this approach has its limitations, particularly when used for extended periods. Therefore, a more effective and sustainable control method is using damper at noise source. This research is focused on maximizing the use of grinting grass as composite material for noise reduction. This research about analysis of noise intensity and safe working distance from noise exposure in the use of Grinting grass (*Cynodon dactylo*n) as noise damper.

METHODS

This experimental research was carried out in the Laboratory of Physics at the Faculty of Mathematics and Natural Sciences, Sebelas Maret University. The equipment used included a mold measuring 50×30×3 cm, natural glue (starch), digital scale, mixer, mixing container, sandpaper, ruler, and marker. Meanwhile, the materials used comprised grinting grass, wood powder, starch, and wooden boards. The step-by-step research procedure was outlined as follows:

- Initial preparation and setup of materials and equipment necessary for the production of biocomposite damper.
- Preparation of the mold according to the predetermined size of the composite.
- The composite assembly process included blending grinting grass composite and wood powder as filler, glued with starch.
- The molding process of damper composite test specimen was subjected to further measurement.
- The composite specimens were molded into a circular shape with a diameter of 15 cm and subjected to a pressure of 60 kg/cm² for 15 minutes at a temperature of 80°C, then cooled until dry and prepared for testing (Table 1).
- The testing of the specimen in the Physics Laboratory of Sebelas Maret University using a Bruel & Kjaer 4206 impedance tube. The composite specimen was placed at the center of the impedance tube, with the sound source positioned at one end of the tube.
- Production of damper from grinting grass and ensuring it fits the dimensions required for the machine.
- The testing of damper composite at the research site and data collection of workplace noise intensity following the mandated procedure (SNI 2008).
- The processing of noise intensity measurement data using the Surfer13 application.
- Analysis of noise intensity measurement data before and after using damper.
- Evaluation of safe working distance measurement data before and after using damper.

The research focused on two key variables, namely noise intensity and safe working distance, both assessed before and after the application of grinting grass as damper. These measurements were conducted in a noise-mapping area. The existing research adopted a pretest-posttest Control

Table 1. Dimension of composite

Composite	Sample fraction (grinting grass composite: wood powder)	Composite weight (g)	Volume (cm^3)	Density (g/cm$_3$)	Thickness (mm)
Composite A	80 : 20	45	118.42	0.38	15
Composite B	70 : 30	48	126.32	0.38	15
Composite C	60 : 40	51	124.39	0.41	15

A B C

Group Design, with data analysis performed using the Wilcoxon test. This statistical test was selected to effectively compare noise intensity before and after the intervention (Sugiyono, 2015).

RESULTS AND DISCUSSION

Based on scanning electron microscopy (SEM) tests, the content of cynodon dactylon compounds including C = 59.99%; O = 34.95%; B = 1.94%; Mg = 1.33%; K = 0.90%; Cl = 0.79%; NI = 0.05%; Cr = 0.03%; Fe = 0.03% (Figure. 1). The largest content of grass is carbon and Carbon is the most compatible matrix for carbon fibers. Carbon fibers in carbon matrix composites (called C/C composites) serve to strengthen the composite because the carbon fibers are much stronger than the carbon matrix due to the crystallographic texture in each fiber. In addition, carbon fibers serve to strengthen the composite because the bond release between the fibers and the matrix provides a mechanism for energy absorption during mechanical deformation (Deborah, 2017).

According to the research by Lathiifah (2021), materials that can absorb sound possess characteristics that are soft, porous, and fibrous. Therefore, grass with such properties can be utilized as an effective noise-dampening composite material. This study examines composite materials made from *Cynodon dactylon* grass and wood powder with varying compositions. The test results of the *Cynodon dactylon* composite specimens with three different compositions tested at frequencies ranging from 250 to 1000 Hz using an impedance tube. Subsequently, the tests yielded the following results:

The highest sound absorption coefficient was found in composite C, surpassing the others by 0.30, as shown in Table 2. This significant

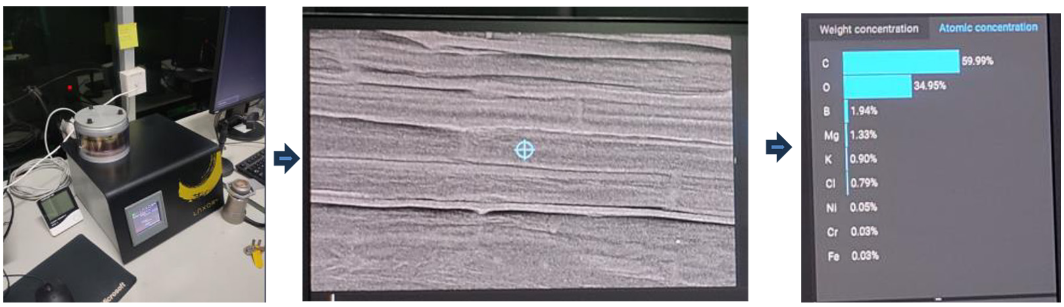

Figure 1. Scanning electron microscopy test of cynodon dactylon grass

Table 2. Sound absorption test results from a combination of grinting grass composite and wood powder

Composite	Sample fraction (grinting grass composite: wood powder)	Sound absorption coefficient (α)			
		250 Hertz	500 Hertz	750 Hertz	1000 Hertz
Composite A	80 : 20	0.16	0.12	0.16	0.15
Composite B	70 : 30	0.14	0.16	0.28	0.23
Composite C	60 : 40	0.17	0.19	0.30	0.19

achievement occurred at a specific frequency of 750 Hz and was attributed to the 60:40 ratio of grinting grass composite and wood powder. The frequency at which this optimal sound absorption coefficient was observed tends to be directly related to the distribution of grinting grass composite. This was consistent with Aristya (2011) that samples composed of 70% organic materials exhibited the highest sound absorption coefficient, followed by those with 90% and 100% organic materials. In simpler terms, a 100% organic sample has the highest density (lowest porosity), while 70% has the lowest density (highest porosity). Consequently, the composite material efficiently absorbed sound energy, which is consistent with Bahri & Suryajaya (2016). It was reported that the sound absorption coefficient of a material typically ranged from 0 to 1. A coefficient of 1 simply implied that all sound energy was absorbed by the material or vice versa. Additionally, Achmad and Syaifullah (2017) stated that all composite material compositions in the research could be used as silencer at frequencies of 750 Hz and 1000 Hz because the resulting sound absorption coefficient met the ISO 11654 requirements, namely $\alpha \geq 0.15$.

In Figure 2, the data showed specific trends in sound absorption coefficients at different frequencies. For instance, sample B showed a lower sound absorption coefficient at 250 Hertz, while A showed a similar pattern at 500 Hertz, both compared to the performance at other frequencies. This lower absorption can be attributed to the sound waves propagated in the tube, where the wavelength (λ) is larger in reflection than absorption by the composite. The highest sound absorption coefficient was observed in sample C at a frequency of 750 Hertz with a value of 0.30. However, it is important to state that this coefficient experienced a decline at 1000 Hertz. This occurs because 1000 Hertz is the optimum frequency at which energy dissipation in the sample increases the sound absorption coefficient (Sinaga et al., 2012). Additionally, this behavior may also be attributed to a known characteristic of acoustic materials, referred to as recessivity, where sound absorption coefficients tend to decrease at specific frequencies.

Sample C showed the highest sound absorption coefficient across different frequencies, with the exception of 1000 Hertz. This was because sample C had the most optimal composition of grinting grass composite, making it easier for the material to absorb sound waves and enhance its absorption coefficient. damper had a sound absorption coefficient (α) less than 0.3, showing high-quality material. This observation is in line with Grades et al. (2021), stating that good damper materials possess a sound absorption coefficient greater than or equal to (≥ 0.3). In addition, Eriningsih (2009) conducted research on sound-absorbing materials, with a specific focus on hemp fiber and waste composite.

The noise-damper composite with the highest sound absorption is found in the composition of 60:40 in composite C (Table 2). A box-shaped composite (50×30×3 cm) was then created and tested on a grinding machine operating for 2 hours per day. The installation of the box composite required perforated plywood (hole of diameter = 3 cm), plywood for attaching the composite damper that covers the entire machine. To create an effective noise damper composite, the choice of plywood layer and the size of the holes have taken into account the thickness of the plywood = 9 mm; this thickness provides better stability and can reduce resonance. Holes with diameters between 2–5 cm are generally effective. A diameter of 3 cm is often used as it provides a good balance between sound penetration

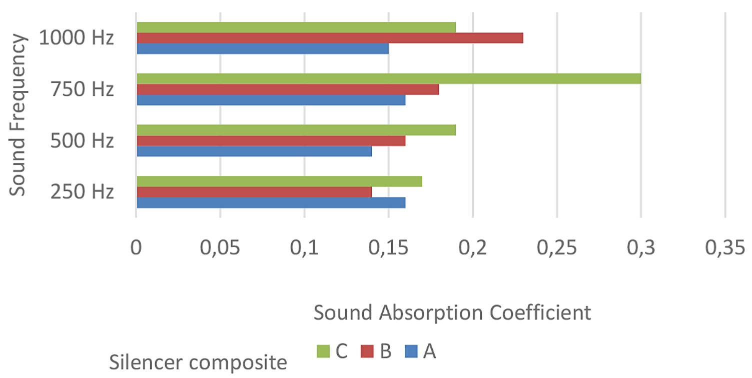

Figure 2. Sound absorption coefficient results of composite

and structural strength. The distance between the holes is regular and not too close; about 15 cm can be a benchmark to ensure optimal soundproofing. Noise measurements were taken at the holes of the composite plywood to obtain accurate results from the noise source. Noise measurements were conducted before and after the installation of the noise damper accordance SNI 19-1714-2008.

The results of the noise intensity measurements before and after the installation of the noise damper are analyzed using surfer13 to determine the noise mapping area. The difference in the noise mapping area before and after the installation of the noise damper proves that the composite damper made of Cynodon Dactylon grass was able to reduce the noise intensity (Figure 3).

Grinting grass damper (sample C), ranges from 90 to 106 dBA, as shown in Table 3. This noise originated from production machines operating for 8 hours per day, with no control measures at the workplace. The specific measurement results of noise intensity are shown in Table 3:

Noise intensity levels, as shown in Table 3, are inconsistent with the Minister of Manpower Regulation Number 5 of 2018 on Occupational Safety and Health in the workplace. In accordance with this regulation, the permissible exposure level for an 8-hour workday or 40 hours per week need not

Figure 3. Measurement of noise intensity after used noise damper composite

Table 3. Measurement results of noise intensity and safe working distance from noise exposure

Measurement location	dBA measurement results	Safe working distance from exposure (m)	dBA measurement results	Safe working distance from exposure (m)
	Before intervention		After intervention	
Point 1	106	6.1	89	2.3
Point 2	98	4.3	85	1
Point 3	96	3.8	84	1
Point 4	97	3.2	83	1
Point 5	91	2.1	84	1
Point 6	98	3.5	85	1
Point 7	102	4.8	87	1.8
Point 8	90	2.1	83	1
Point 9	98	3	86	1.5
Point 10	98	3	84	1
Point 11	105	5	88	2
Point 12	100	3.5	87	1.8
Point 13	98	2.8	85	1
Point 14	90	2	84	1
Point 15	100	3	86	1.5
Equivalent noise level (dBA)	97.85		85.35	

Note: m – meter, dBA – decibel.

surpass 85 dBA. Meanwhile, the regulation allows exposure to noise levels of 106 dBA for a maximum duration of 7.5 minutes per day. Sasmita et.al. (2018), Anshari et al. (2018), and Fredianta et.al. (2013) stated that the maximum exposure time decreased with higher noise intensity levels.

According to Suma'mur (2014), it is essential to implement effective workplace noise control management. Technological engineering requires damper, which is a form of noise control. These are installed in machines or equipment that produce high noise levels, typically through a build-up process, leading to a significant reduction in noise levels. The National Institute for Occupational Safety and Health (1998), Indonesia, has set the noise threshold limited value for workplaces at 85 dBA. Prolonged exposure beyond TLV for an extended period can lead to Noise-Induced Hearing Loss (NIHL). The results obtained before and after using damper on the production machines depicted a reduction in noise intensity, as shown in Figure 4.

The most significant reduction in noise intensity, occurred at points 1 and 11, with an average of 16%, as shown in Figure 3. However, this value still exceeds the permissible limit because the production machines are closely positioned, resulting in the accumulation of noise from multiple sources at the measurement points. The smallest noise reduction was observed at point 14 by only 6.7%, due to the distance from the production machines as well as the location near the door and ventilation area.

Significant reductions in noise intensity, well below the permissible limit, were observed at points 4 and 10, showing a 14% decrease. This was attributed to the fact that point 4 is far from the production machines and close to a wide corridor leading to the parking area. Similarly, point 10 had a substantial reduction in noise due to its proximity to the exit door of the production area.

Silencer made from grinting grass effectively reduced noise by an average of 12.47%, at an effectiveness rate of 60%, and recycled resources often considered weeds in the agricultural sector. Khuriati (2006), Thamrin (2013), and Yang et al. (2003) examined the development of sound-absorbing material with the use of eco-friendly organic fiber or particle, which led to the design of related organic silencer. This silencer requires using materials such as coconut coir, wood powder, rice straw, palm tree fiber, etc.

The results of the noise intensity measurements taken before and after the installation of the Cynodon dactylon noise damper composite were input into Surfer 13 software to display a noise mapping areas and to indicate safe working distances. Below are the results of the noise mapping area showing the differences before and after the installation of the noise damper:

The intervention results are evident in the shifting color zones, where the red areas have transitioned into yellow and yellow areas into green, as shown in Figure 5. The points in the red and yellow areas, show that noise intensity tends to exceed the permissible limits. The use of noise distribution mapping with color-coded zones in the workplace served as a valuable control tool. It provides real-time information to workers about the exposure to increased noise levels in acceptable time frames and also assists industries in selecting appropriate control measures. This approach is in line with Casas et al. (2014) that noise mapping in industries aids in predicting distribution patterns in workplace areas, thereby facilitating the formulation of effective regulations for noise control or mitigation.

Based on Figure 3, the distribution of noise exposure points showed that the highest measurement recorded at point 1 reached 106 dBA. In this scenario, work was performed for 8 hours

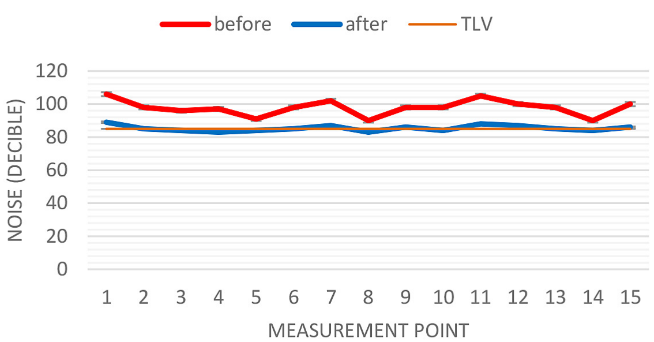

Figure 4. Noise intensity before and after using damper

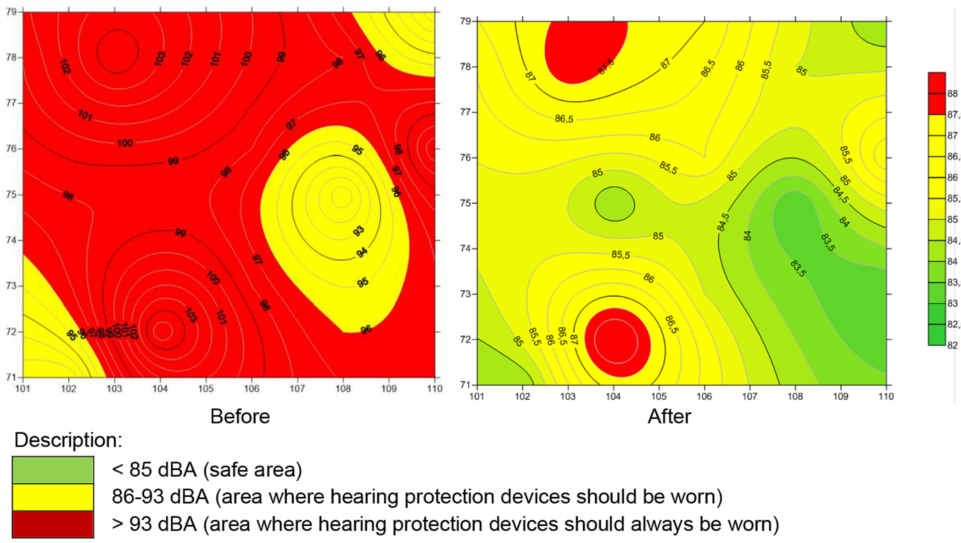

Figure 5. Noise mapping area before and after used damper

daily, stressing the importance of maintaining a safe working distance of 6.1 m to ensure safety. In accordance with the Minister of Manpower Regulation Number Number 5 of 2018, exposure to a noise intensity of 106 dBA is only permissible for a maximum duration of 3.75 minutes. To avoid continuous exposure to high noise levels at the same point, task rotation or alternation was recommended. The results of noise mapping in the workplace showed the propagation range of sound-conducting airwaves from noise source or machines in the production area. Noise intensity decreased as the distance from the source increased. The highest noise intensity was observed in the production area of the animal feed industry, mainly due to the proximity of multiple machines in a 4 m radius, which resulted in a wide sound wave propagation pattern. This is consistent with Andaningsari and Rahman (2023) that the propagation pattern depends on noise level and the distance between locations, with closer ones leading to higher ambient noise levels. According to Sasmita et al. (2021), this sound propagation pattern adversely affects health and leads to disturbances among workers.

Noise mapping is a critical tool that provides essential information to workers regarding exposure exceeding the permissible limit, thereby requiring attention to avoid health disturbances. This approach is in line with Aryo and Berliani (2021) and Romi et al. (2022), that noise mapping shows noise distribution pattern used as the basis for control efforts. According to Ikmalul et al. (2022), the results of noise mapping obtained using Surfer software showed the area affected by the operational machines of the ULPL Ampenan power plant.

Noise distribution mapping in the workplace showed a change in the red area to yellow and green, supported by a statistically significant test result. The Z value of -3.529 and Asymp.Sig (2-tailed) of 0.000 < 0.05 depicted a decrease from high to lower noise intensity, with some levels falling below the threshold limited value. There was a significant difference in noise intensity before and after using grinting grass as damper. Syarah et al. (2019) conducted similar research using organic materials, namely rice husks and straw as dampers, and reported a significant difference in noise intensity before and after treatment. Moreover, Oktavia et al. (2016) stated that using coconut husks containing ligno-cellulose as damper resulted in an average noise intensity of 11.78 dBA, decreasing from 94.85 dBA to 83.07 dBA.

The test result showed a Z value of -3.410 and Asymp.Sig (2-tailed) of 0.001 < 0.05, implying a difference in safe working distance from noise exposure before and after using grass composite as damper. This change is evident in noise mapping, where the area previously characterized by high noise levels close to the production machines was marked in red, thereby advising workers not to be in approximately 1 m of the source. However, after using damper, the area transitioned to yellow, allowing workers to be in 1 m of the source under supervision and in a specified time. Syarifuddin (2015) stated that the yellow area, located farther from noise source, experienced less noise production. Workers in the yellow area are still advised to use ear protection devices, such as earplugs or earmuffs, to protect the hearing and overall health.

Maintaining a safe distance from noise source is a practical means of limiting workplace exposure to high noise levels, thereby preventing negative consequences. This practice is in line with Ridley (2008) that the human ear cannot accommodate sounds louder than 115 dBA and stated the need for ear protection devices when exposed to levels exceeding 85 dBA for extended periods. Damayanti (2019) stated that source, the main component of sound control, was generated, and the path depicts the sound route through the air to reach the receiver or the ear. Effective noise management requires reducing the intensity of sound reaching the ear by establishing a safe working distance from noise source, with or without the use of ear protection devices.

CONCLUSIONS

In conclusion, the highest sound absorption coefficient of 0.30 was observed in composite C, composed of 60% grinting grass composite and 40% wood powder at a frequency of 750 Hertz. Damper made from grinting grass composite effectively reduced noise by an average of 12.47% at a discernible safe working distance of 1 meter.

Based on the test results obtained, the objective of exploring the physical and chemical properties of the Cynodon dactylon grass fiber composite has been clearly achieved. The findings of this research reveal that the Cynodon dactylon grass fiber composite has sound absorption strength that can compete with conventional composite materials. Many researchers have utilized natural fibers from various composite materials, but the use of grass as a damper composite, particularly Cynodon dactylon, remains relatively unexplored.

This composite is produced using a starch-based adhesive that is not durable, as starch can absorb moisture from the environment, which can reduce the adhesive strength and lead to delamination in the composite. These findings open prospects for further development in the utilization of Cynodon dactylon grass fiber composites, especially in construction applications and eco-friendly products from grass fiber composites that have not been extensively explored by other researchers.{Gurauskiene, 2006, Eco-design methodology for electrical and electronic equipment industry}

REFERENCES

1. Achmad K., Syaifullah. 2017. Pembuatan Dan Karakterisasi Partikel Komposit Kayu Karet Sebagai Material Peredam Suara. Prosiding SNRT (seminar Nasional Riset Terapan) Politeknik Negeri Banjarmasin, 9: C80-C88. https://e-prosiding.poliban.ac.id/index.php/snrt/article/view/109
2. Andianingsari, D., Rahman. 2023. Pemantauan Kebisingan dengan Menggunakan Peta Kebisingan Program Suffer. ISTA online Technologi Journal. 4(1): 38-53. https://iontech.ista.ac.id/index.php/iontech/article/view/81
3. Anshari MH., Artika KD., Kuswoyo A. 2018. Analisa Pengukuran Tingkat Kebisingan Sepeda Motor Berdasarkan RPM dan Jumlah Kendaraan. Jurnal Elemen. 5(1): 7-10. https://www.academia.edu/64914749/Analisa_Pengukuran_Tingkat_Kebisingan_Sepeda_Motor_Berdasarkan_RPM_Dan_Jumlah_Kendaraan
4. Aristya S.A. 2011. Nilai Serapan Bunyi (Noise Absorption Coefficient) dari Komposit Serbuk Gergaji Kayu Sengon dengan Matrik Alami. Tugas Akhir. Fakultas Teknologi Industri, Universitas Islam Indonesia, Yogyakarta. https://dspace.uii.ac.id/handle/123456789/34103
5. Aryo S., Berliani O. 2021. Noise Mapping and Analysis of Maximum Exposure Time in Rubber Processing Industries. Journal of Industrial Hygiene and Occupational Health. Vol. 6, No. 1, Oktober 2021: 35-48. http://dx.doi.org/10.21111/jihoh.v6i1.6120
6. Bahri, S., Manik, T. dan Suryajaya. 2016. Pengukuran Sifat Akustik Material Dengan Metode Tabung Impedansi Berbasis Platform Arduino. Jurnal Fisika FLUX, 13(2). http://dx.doi.org/10.20527/flux.v13i2.3460
7. Casas, W.J.P., E.P. Cordeiro, T.C. Mello, and P.H.T Zannin. 2014. Noise Mapping as a Tool for Controlling Industrial Noise Pollution. Journal of Scientific & Industrial Research. 73: 262-266. https://nopr.niscpr.res.in/bitstream/123456789/27742/1/JSIR%2073(4)%20262-266.pdf
8. Damayanti, E. 2019. Perbedaan stress kerja berdasarkan asa kerja karyawan di bagian weaving li PT Dan Liris sukoharjo tahun 2019. Poltekes Kemenkes Surabaya. http://repo.poltekkesdepkes-sby.ac.id/id/eprint/1192
9. Erininsih, R. 2009. Komposit Serat Rami dan Limbah Rami Sebagai Bahan Absorbi Suara, Balai Besar Tekstil Arena Tekstil. 24(1). https://perpustakaan.stttekstil.ac.id/index.

php?p=show_detail&id=9873&keywords=

10. Eriningsih, R., Mutia, T., Judawisastra, H. 2011. Komposit Sunvisor Tahan Api dari Bahan Baku Serat Nanas, Jurnal Riset Industri, Vol. V, No. 2, 191–203. https://www.neliti.com/id/publications/178823/komposit-sunvisor-tahan-api-dari-bahan-baku-serat-nenas
11. Erwan, Faryuni, I.D., Wahyuni, D. 2015. Sintesis Dan Analisis Sifat Fisik Dan Mekanik Papan Komposit Dari Limbah Pelepah Sawit Dan Sabut Kelapa. Prism. Fis. III, 47–50. http://dx.doi.org/10.26418/pf.v3i3.13893
12. Fajri R. 2015. Pengukuran Koefisien Absorbsi Material Akustik dari Serat Alam AMpas Tebu (Bagasse) sebagai Pengendali Bising. Diploma thesis. Fisika MIPA. Universitas Andalas. Penerbit: e-Skripsi Universitas Andalas. https://doi.org/10.25077/jif.7.1.1-6.2015
13. Farid, M., Putra, A., Abdullah, Y., Efendy, H., Ayob, R., dan Sajidin, M. 2012. Untilizing Sugarcane Wasted Fibers As A Sustanable Acoustic Absorber, Procedia Engineering, 53, 632-638. (https://doi.org/10.1016/j.proeng.2013.02.081)
14. Fredianta D., Huda LN., Ginting E. 2013. Analisis Tingkat Kebisingan Untuk Mereduksi Dosis Paparan Bising di PT. XYZ. e-Jurnal Teknik Industri FT USU. 2(1): 1–8 (https://www.neliti.com/publications/219272/analisis-tingkat-kebisingan-untuk-mereduksi-dosis-paparan-bising-di-pt-xyz#id-section-content)
15. Grades, A., Reza M., Rozi R.M. 2021. Mapping and calculation of exposure to noise levels in the wood processing industry in Siak District, Riau province. Journal of Environmental Engineering. 6(2): 68-76. https://doi.org/10.29080/alard.v6i2.1185
16. I Made A, I.G.K.D. 2016. Karakterstik Serapan Suara Komposit Polyester Berpenguat Serat Tapis Kelapa. J. Din. Tek. Mesin 6. (https://www.neliti.com/publications/59771/karakterstik-serapan-suara-komposit-polyester-berpenguat-serat-tapis-kelapa)
17. ISO 11654. 1997. Australian Standard TM Acoustical Sound Absorbers for Use in Building-Rating of Sound Absorbtion,
18. ISO 10534-2: Acoustics – Determination of sound absorption coefficient and impedance inimpedance tubes – Part 2: Transfer-Function Method. 1998. International Standardization Organization.
19. Kartikaratri, Y.M., Agus, S., dan Hendri, W. 2012. Pembuatan Komposit Serat Serabut Kelapa Dan Resin Fenol Formadehide Sebagai Material Peredam Akustik, Jurnal Berkala Fisika, 15(3), UNDIP, hal 87-90. https://ejournal.undip.ac.id/index.php/berkala_fisika/article/view/4989
20. Khuriati A., Nur M. 2006. Disain Peredam Suara Berbahan Dasar Sabut Kelapa dan Pengukuran Koefisien Penyerapan Bunyinya. Jurnal Berkala Fisika. 9(1). hal 15-25, https://ejournal.undip.ac.id/index.php/berkala_fisika/article/view/3107
21. Ikmalul H., Wahyudin., Erlan S., Azwaruddin. 2022. Mapping of noise levels due to operational aktivities of PT PLN (Persero) ULPL ampenan power generation machines in the Tanjung Karang Area. Jurnal Sanitasi dan Lingkungan. 3(1), 223–238 https://e-journal.sttl-mataram.ac.id/index.php/jsl/article/view/51/34
22. Marselinus H., Jeni P.P., Merry C.N. 2020. Identifikasi Hijauan Makanan Ternak di Lahan Pertanian dan Padang Penggembalaan Haharu Kabupaten Sumba Timur. JITRO (Jurnal Ilmu dan Teknoloi Peternakan Tropis), 8(1): 42–50. https://doi.org/10.33772/jitro.v8i1.14601
23. Milawarni S. 2017. Pembuatan Plazore dari Plastik Bekas dengan Media Minyak Jelantah dan Aplikasi sebagai Peredam Bunyi. J. Teknol. Kim. Unimal 2, 52–62. https://doi.org/10.29103/jtku.v6i2.475
24. Mutia, T., Sugesty, S., Hardiani, H., Kardiansyah, T., Risdianto, H., 2016. Potensi Serat Dan Pulp Bambu Untuk Komposit Peredam Suara. J. Selulosa 4, 25–36. https://doi.org/10.25269/jsel.v4i01.54
25. National Institute for Occupational Safety and Health (NIOSH). 1998. Occupational Noise. Exposure Revised Criteria. Cincinnati. Ohio
26. National Institute of Occupational Safety Hazards (NIOSH). 1998. Criteria For A Recommended Standard: Occupational Noise Exposure. U.S Department Of Health And Human Service: Ohio.
27. Oktavia S.W., Sri M., Yamtana. 2016. Pemanfaatan Coconut Dust dalam Kotak Sengon Sebagai Peredam Kebisingan Mesin Diesel Penggilingan Padi di Usaha Dagang Sumber Barokah. Sanitasi, JurnalKesehatan Lingkungan. 7(4). Hal 181–186. https://doi.org/10.29238/sanitasi.v7i4.728
28. Peraturan Menteri Ketenagakerjaan Republik Indonesia Nomor 5 Tahun 2018 tentang Keselamatan dan Kesehatan Kerja Lingkungan Kerja
29. Pratiwi, P., Fahmi, H., Saputra, F., 2017. Pengaruh orientasi serat terhadap redaman suara komposit berpenguat serat pinang. J. SIMETRIS 8, 813–818. https://doi.org/10.24176/simet.v8i2.1617
30. Ridley J. 2008. Kesehatan dan Keselamatan Kerja. Jakarta. Erlangga
31. Romi A., Febri J.I.A., Yasdi. 2022. Intensitas Bising dan Pemetaan Kebisingan dengan Surfer 13 di Lingkungan Kerja PT Hok Tong Jambi. Rekayasa Hijau: Jurnal Teknologi Ramah Lingkungan. 6(3), 197–207. https://doi.org/10.26760/jrh.v6i3.197-207
32. Sasmita A., Asmura J., Ambarwati NR. 2018. Pengendalian kebisingan dengan metode conceptual model di pabrik kelapa sawit PT. Tunggal perkasa plantations. Jurnal Sains dan Teknologi; 17(2): 61–68 (https://jst.ejournal.unri.ac.id/index.php/JST/

article/view/7485/6534)

33. Sasmita A., Asmura J., Rian A.N. 2018. Pengendalian Kebisingan Dengan Metode Conceptual Model Di Pabrik Kelapa Sawit PT. Tunggal Perkasa Plantations. J Sains dan Teknol. 17(2): 61. (http://dx.doi.org/10.31258/jst.v17.n2.p61-68)
34. Sasmita, A., M. Reza., dan R.M. Rozi. 2021. Pemetaan dan Perhitungan Pemaparan Tingkat Kebisingan pada Industri Pengolahan Kayu di Kecamatan Siak, Provinsi Riau. Jurnal Teknik Lingkungan. 6(2): 68-76. https://doi.org/10.29080/alard.v6i2.1185
35. Sinaga, D., Defriyanto, I., dan Krisman, M. 2012. Pengukuran koefisien Absorbsi Bunyi dari Limbah Batang Kelapa Sawit, Jurnal Fisika, UNRI, 9(5), 415–423. http://dx.doi.org/10.31258/jkfi.9.5.415-423
36. Standar Nasional Indonesia (SNI) 7231 Tahun 2009 Metoda Pengukuran Intensitas Kebisingan di Tempat Kerja
37. Sugiyono. Metode "Penelitian & Pengembangan (Research and Development/R&D)" Penerbit Alfabeta. Bandung; 2015
38. Suma'mur, P.K. 2014. Higiene Perusahaan dan Kesehatan Kerja. Jakarta: Sagung Seto.
39. Syarah N.K.HS., Yuliani S., Bina K. 2019. Analisis penggunaan sekam padi dan Jerami Sebagai Peredam Suara Mesin Diesel Pada Tingkat Kebisingan Lingkungan Kerja Penggilingan Padi. Jurnal Kesehatan Masyarakat. 7, 354-361. (https://doi.org/10.14710/jkm.v7i4.24602)
40. Syarifuddin, M. 2015. Analisis Penentuan Pola Kebisingan Berdasarkan Nilai Ambang Batas Pada Power Plant di PT Arun NGL. Malikussaleh Industrial Engineering Journal, 4(1), 36–41. https://doi.org/10.53912/iejm.v4i1.44
41. Thamrin S., Tongkukut SHJ., As'aria. 2013. Koefisien Serap Bunyi Papan Partikel Dari Bahan Serbuk Kayu Kelapa. Jurnal Mipa Unsrat Online. 2(1): 56–59. https://doi.org/10.35799/jm.2.1.2013.961
42. Yang, H, Jun KD., Joong KH. 2003. Rice Straw-Wood Particle Composite For Saund Absorbing Wooden Construction Materials. Bioresource Technology. 86: 117–121. 10.1016/s0960-8524(02)00163-3