Journal of Applied Engineering and Technological Science
Vol 4(2) 2023: 734-742

THE POTENTIAL OF SAWDUST AND COCONUT FIBER AS SOUND-REDUCTION MATERIALS

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Received : 04 June 2022, Revised: 02 February 2023, Accepted : 05 February 2023
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ABSTRACT
In this study, biodegradable materials that could be utilized to reduce noise were examined. Sound absorption test was conducted with an impedance tube. Sawdust, coconut fiber, and expansive clay were used to create test samples. Noise reduction coefficient results for sawdust and expansive clay mixture ranged from 0.24 to 0.62. A mixture of coconut fiber and expansive clay recorded in noise reduction coefficient between 0.31 and 0.58. Coconut fiber mixed with expansive clay recorded noise reduction coefficient ranging from 0.31 to 0.58. The study findings suggests that these materials have good acoustic properties and can therefore be used as alternative noise reduction materials. These findings have important implications in reducing environmental pollution if adopted in the development of noise reducing materials.
Keywords: *Noise Reduction Coefficient (NRC), Acoustic Properties, Coconut Fiber, Saw Dust, Noise Pollution*

1. Introduction

In the industrial society today, noise pollution has become a major source of health problem facing humanity and the environment (Gheorghe, 2013). Noise is a nuisance experienced by humans as a result of machines and equipment used in everyday activities (Indrianti et al., 2016). It is also considered to be unwanted sound that is usually unpleasant, loud, or disturbing to the hearing organs and is considered to be one of the negative environmental health hazards (Vašina, 2022). Sound, in fact, is the transmission of a disturbance in a fluid or solid, most commonly in the form of a wave motion, which is initiated when an element moves the nearest particle of air, causing a pressure differential in the medium through which the wave travels (Goelzer et al., 2001).

Sound propagates at different speeds depending on the medium through which it passes and the pressure differential (Breysse & Lees, 2006). Most mechanical devices, including industrial equipment, home appliances, cars, and houses, have Noise and vibration associated with them (Navhi et al., 2009; Rmili et al., 2009). Noise and vibration are not always a nuisance, they can be used as the source of signals for machinery diagnostics and health monitoring (Randall, 2009; Tuma, 2009). Many workers are exposed to higher levels of noise above the approved threshold. Some negative effects posed by noise pollution on human health include, hearing problems, physical or mental losses, annoyance, and tiredness, among others. As a result, public knowledge and education about the effects of noise pollution and how it can be minimized is needed (Abd-elfattah & Abd-Elbasseer, 2011). It is therefore necessary to eliminate or reduce excessive noise. This is done by converting the excessive mechanical energy of oscillating motion causing noise and acoustic energy into other types of energy, especially heat (Vašina, 2022).

At the current state of development in technology, noise tends to be an inevitable problem in the society. Noise being an occupational hazard, controlling and reducing it to the barest or tolerable levels for human comfort is a worthwhile challenge to be addressed using available local materials to cut down cost of importation of conventional materials. Achieving a manageable noise level would depend on the material used. Vibration isolation, partitions, sound-absorbing materials, device enclosures, and other enclosures can be used to reduce noise and vibration in mechanical systems if the sources of noise and vibration are identified (Roozen et al., 2009; Upadhyay et al., 2009). Eliminating noise completely, may not be possible since the environment could not be changed entirely. Continuous exposure, however, may pose health risk far beyond hearing damage. It is therefore necessary to put in place measures to reduce it to a manageable level.

Depending on the type of noise and vibration generated, controlling the noise and vibration waves is always a physical challenge, requiring adequate control mechanisms that are practical (Tuler & Kaewunruen, 2017). To increase the efficiency of these sound-absorbing materials, they are used in combination with barriers and within enclosure (Crocker & Arenas, 2007). Materials that absorb and transmit sound waves should be able to absorb and transmit more sound waves than they reflect (Doutres & Atalla, 2012). The ability of a material to absorb sound is influenced by its thickness, density, and porosity (D'Alessandro & Pispola, 2005). At low frequencies (100-2000Hz), the material thickness is relevant or has a direct link; at high frequencies (>2000Hz), it is irrelevant (Seddeq, 2009). Porosity, aggregate size, aggregate gradation, aggregate type, and specimen thickness are the key parameters that influence sound absorption properties of porous materials (Zhang et al., 2020). The sound absorption coefficient increases as the thickness of the samples rises, according to Azkorra et al., (2015). The explanation for this may be that low frequency waves had longer wavelengths, implying that thicker material led to better absorption (Adnan & Rus, 2013). Density influences the acoustic impedance since the impedance determines the reflection of materials; the impedance is proportional to the density. According to Wertel (2000), a high-density material absorbs more sound because of its mass (Wertel, 2000).

Most of the research into the sound absorption characteristics of materials is on synthetic materials. Muhazeli et al., (2020) studied the sound-absorption properties of a magneto-induced foam or magnetorheological foam by adding different concentrations of carbonyl iron particles. They discovered that the introduction of a magnetic field resulted in a peak frequency shift from the middle to higher frequency ranges which had a significant influence on sound absorption, and concluded that the magnetorheological foam could be applied as a material to control noise. Monkova et al., (2020) studied the sound absorption capabilities of 3D printed open porous acrylonitrile butadiene styrene (ABS) samples that were printed with four different lattice structures namely: Cartesian, Starlit, Rhomboid, and Octagonal; and concluded that 3D printed materials were good in sound absorption and could be used industrially as such. Liang et al., (2022) studied the use of inorganic materials, especially their fibers in sound and noise absorption and noted that the acoustic properties of polymers were usually improved by adding fillers, using perforated structures, gradient porous structures, and multiple-layer composite structures. In their study, Qunli Chen et al., (2022) investigated the performance of aluminum silicate fibers and other materials and successfully proved that the pure aluminium silicate fibers performed very well in absorbing low frequency noise compared with the others. They also confirmed that the thicker the material and higher the density of the material the higher its noise absorption ability.

Development of new synthetic sound absorption materials is well advanced and successful, but these materials are expensive since they are mostly synthesized from petroleum-based resources, and consequently, contribute to adverse environmental effects like global warming and climate changes (Galbrun & Scerri, 2017). Most materials for acoustic applications today, like synthetic plastics, glass wool, and synthetic foams, are harmful to human health, and pose a threat to social life and the environment (Sailesh et al., 2022). The proliferation of synthetic plastics is being corrected at all levels of humanity (Hong & Chen, 2017). Sailesh et al., (2022) investigated sound absorption and transmission loss characteristics of 3D printed bio-degradable material made with Poly Lactic Acid (PLA). Even though it has long life and is bio degradable, it still needs to be hydrolyzed at high temperature using micro-organisms in industrial composting facilities to be compostable (Karamanlioglu et al., 2017). That means they are not naturally bio-degradable but requires effort and money to compost them.

Presently, most sound absorption materials available commercially consists of glass or mineral-fiber material, however, today's public consciousness and concern is to prevent pollution's harmful effects by favouring more friendly fabrics, less polluting practices, and recycled items (Asdrubali, 2006). As a result, it is critical to expand research into finding alternative acoustical materials made from renewable resources such as natural fibers.

Natural fibers are known to have good acoustic properties and are relatively less expensive, biodegradable, abundant, and eco-friendly (Taban et al., 2019). The use of natural fiber and agricultural products as sound-absorbing materials have been investigated by some researchers (Taban, Amininasab, et al., 2021; Yang et al., 2020). Taban et al., (2021) investigated the possibility of producing low-cost sound-absorbing panels from date palm waste fibers and concluded that it could be used to enhance room acoustics properties. Or et al. (2017) investigated the acoustic properties of sound absorbers made from raw palm empty fruit bunch and discovered that at the frequency ranges above 1000 Hz, the average Sound Absorption Coefficient of 0.9 could be achieved. There is therefore the potential of using natural materials to absorb sound and for that matter, noise. The need to investigate and find alternative natural fibers that have potential of absorbing low frequency sounds and noise for possible industrial use and for that matter, promote the use of renewable resources for a better ecology is therefore paramount. Such viable alternatives should be materials that do not interfere with human health. It is therefore necessary to explore an opportunity to look for less expensive bio-degradable local materials to be used, as alternative noise reducing material.

This study considers the use of natural fibers and natural renewable and biodegradable materials like coconut fiber, saw dust and clay which are abundant, cheaper, pose less health risk and safety concern, during handling, processing and use.

3. Research Methods

Materials selection

In this study, sawdust and coconut fiber which is generally discarded as waste were gathered and used as the main materials. The coconut fiber was extracted manually from the outer shells of mature coconut fruits and left to dry in the sun. It was then brought to the grinding machine where the coconut fiber was milled into smaller particles. Sawdust was sieved into micron and referred to in this work as fine grade sawdust. Tables 1 and 2 presents the mix proportions and properties of materials used to develop the test specimen, whereas Figure 1 shows the images of the test specimen. The table consist of the materials with their respective proportions on weight basis. They were further mixed with a binding agent in the ratio 1:2 (Particle: Binder). Samples formed from these mix proportions were used to carry out the experiment.

Table 1 - Proportions of materials used in the study.

Sample	Proportions on weight basis			
	Coconut fiber	Fine grade sawdust	Expansive clay	Binder
a	1	1	-	2
b	-	1	-	2
c	1	1	1	2
d	-	1	1	-
e	1	-	1	-

a b c d e

Fig 1. Test specimens, (a) mixture of fine grade sawdust and coconut fiber, (b) fine grade sawdust; (c) mixture of coconut fiber, fine grade sawdust and expansive clay, (d) a mixture of fine grade sawdust and expansive clay. (e) mixture of coconut fiber and expansive clay

Table 2 - Properties of the materials developed.

Sample	Thickness (mm)	Mass (kg)	Volume (m^3)	Density (kg/m^3)
a	30.4	0.244	1.339×10^{-4}	1.823×10^{3}
b	30.3	0.194	1.339×10^{-4}	1.449×10^{3}
c	30.6	0.203	1.339×10^{-4}	1.516×10^{3}

d	30.3	0.242	1.339×10^{-4}	1.808×10^{3}
e	30.1	0.157	1.339×10^{-4}	1.172×10^{3}

Experimental Setup

The measurement of sound level at the given frequencies was conducted using the impedance tube**.** The experimental setup, as shown in Figure 2, consists of an impedance tube with sample holder, a signal generator, a precision digital sound level meter (DT8852), a speaker inserted at one end, and a laptop computer to log the data recorded by the sound level meter. The impedance tube was set-up using ISO 10534-2 standard (Tao et al., 2015). A signal generator connected to a speaker was used to generate the sound at given frequencies for the experiment. The selected frequencies used to investigate the sound level ranged from 1 kHz to 8 kHz. Sound levels were recorded using sound level meter in decibels (dBA), before and after placing developed samples into the test tube holder.

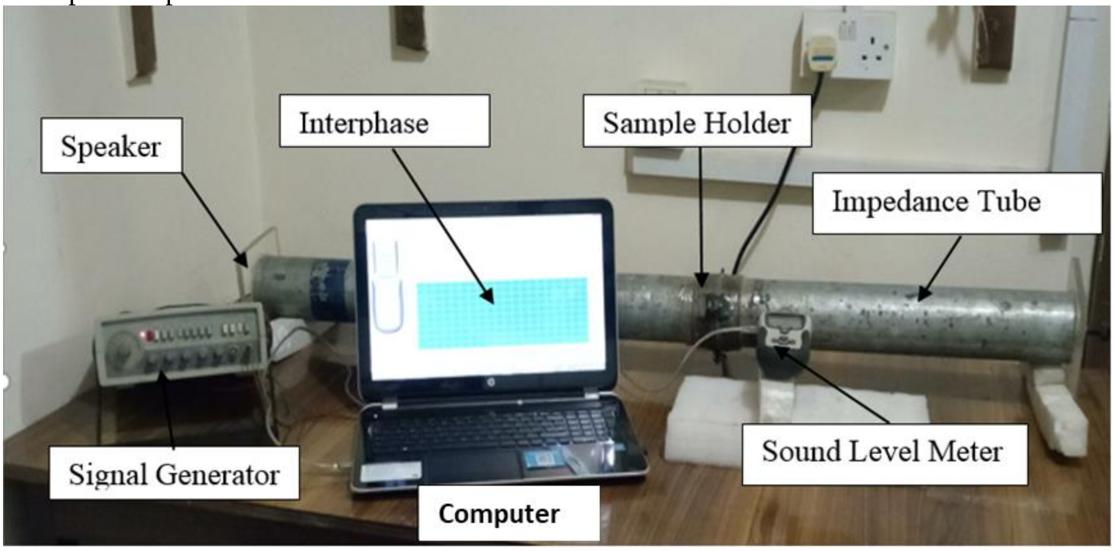

Fig. 2. Experimental setup for sound reduction measurement

Table 3 shows measurements of sound pressure level at the frequencies of 1 - 8 kHz inclusive, in decibel (dBA), without samples of the materials developed in place. These materials were investigated within the frequency range of 1 - 8 kHz inclusive, at 0.5 kHz intervals.

Table 3 - Measured sound pressure level at different frequencies without samples.

Frequency	Sound level without test sample	Sound level without test sample	Sound level without test sample
(kHz)	(dBA) Day 1	(dBA) Day 2	(dBA) Day 3
1.0	96.4	83.9	97.6
1.5	97.2	84.7	96.0
2.0	99.5	84.7	95.0
2.5	99.4	84.5	86.3
3.0	98.7	84.5	85.0
3.5	99.8	84.7	88.6
4.0	98.7	84.5	98.8
4.5	99.2	84.3	84.3
5.0	89.7	84.5	82.1
5.5	97.1	84.5	82.9
6.0	90.8	84.3	86.2
6.5	95.7	84.3	86.7
7.0	92.4	84.3	73.4
7.5	97.7	84.3	80.6
8.0	94.9	84.3	70.4

Table 4 shows measurements of sound pressure level at different frequencies, in decibel (dBA), with samples of the materials developed in place. These materials were investigated within the frequency range of 1 - 8 kHz inclusive, at 0.5 kHz intervals.

Table 4 - Sound pressure level at different frequencies in dBA for samples developed.

Frequency	Fine grade sawdust	Fine grade coconut fiber	Fine grade Sawdust mixed with Coconut fiber	Fine grade sawdust mixed with expansive clay	Coconut fiber mixed with expansive clay
(kHz)	(dBA)	(dBA)	(dBA)	(dBA)	(dBA)
1.0	53.4	68.1	59.2	58.1	56.6
1.5	48.9	76.9	53.9	48.4	48.9
2.0	51.0	73.7	53.6	52.6	49.6
2.5	47.6	60.5	57.2	53.0	59.6
3.0	55.8	69.8	58.5	47.4	56.9
3.5	52.1	68.7	47.0	39.6	45.3
4.0	46.0	56.1	58.5	37.8	54.0
4.5	43.0	54.1	54.4	42.3	40.2
5.0	49.4	44.7	56.4	40.4	50.4
5.5	57.5	62.4	56.1	54.0	45.9
6.0	47.2	70.9	49.9	51.1	36.3
6.5	39.9	65.2	44.2	43.4	36.8
7.0	43.5	55.5	45.0	55.5	43.8
7.5	47.8	62.2	40.1	38.2	38.6
8.0	40.5	58.8	41.4	34.6	41.5

From Equation (1), the effectiveness of the Noise Reduction Coefficient (NRC) of each material developed at the given frequencies were determined and represented in Table 7.

Noise Reduction Coefficient (NRC) = $(a-b)/a$

Where, a is sound intensity in decibel (dBA) without material developed.

b is sound intensity in decibel (dBA) with material developed in place

4. Results and Discussions

Effects of different biodegradable material composition on NRC

This section summarizes and discusses the main findings of the work. The NRC results are given in Table 5 and shown graphically in Figure 3. Based on the results, it was observed that NRC values ranged between 0.09 for coconut fiber at 1 kHz frequency and 0.62 for fine grade sawdust mixed with expansive clay at 4.0 kHz. By carefully examining the data, it is found that fine grade sawdust mixed with expansive clay yielded the highest NRC value of 0.62 at 4 kHz. The other samples used in this study also show promising NRC values. The high NRC value of fine grade sawdust mixed with expansive clay may be attributed to the material's high density. This is consistent with the findings of Wertel (2000) which suggest that high-density material absorbs more sound because of its mass. Results further show that, materials with high density have good sound reduction properties due to their high NRC values. Further work to improve on these samples' NRC values is suggested.

Table 5 - Noise Reduction Coefficient (NRC) for the Samples

Frequency (kHz)	Noise Reduction Coefficient (NRC)				
	Fine grade sawdust	Coconut fiber	Fine grade sawdust mixed with Coconut fiber	Fine grade sawdust mixed with expansive clay	Coconut fiber mixed with expansive clay
1.0	0.45	0.18	0.39	0.4	0.42
1.5	0.49	0.09	0.44	0.5	0.49
2.0	0.46	0.13	0.44	0.45	0.48
2.5	0.45	0.28	0.34	0.39	0.31
3.0	0.34	0.17	0.31	0.44	0.33
3.5	0.41	0.19	0.47	0.55	0.49
4.0	0.53	0.34	0.41	0.62	0.46
4.5	0.49	0.36	0.35	0.5	0.52
5.0	0.40	0.47	0.31	0.51	0.39
5.5	0.31	0.26	0.32	0.35	0.45
6.0	0.45	0.16	0.42	0.41	0.58
6.5	0.54	0.23	0.49	0.5	0.58
7.0	0.41	0.34	0.39	0.24	0.4

7.5	0.41	0.26	0.50	0.53	0.52
8.0	0.42	0.30	0.41	0.51	0.41

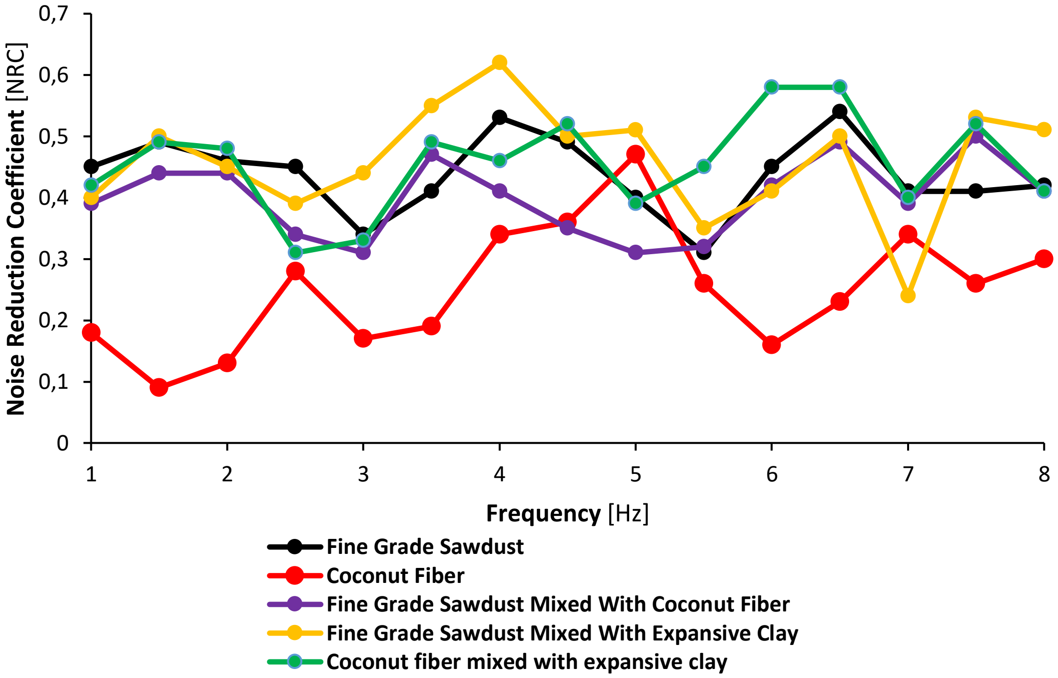

Fig. 3. The noise reduction coefficient graph for the samples at various frequencies

Comparison of NRC results with literature

Table 6 presents the study's best NRC results (Fine grade sawdust mixed with expansive) together with other NRC results of different materials from previous studies (Balan and Asdrubali, 2006; Tengku Izhar et al., 2015; Oancea et al., 2018; Shivasankaran, 2019). The other sample compositions compared with the present study sample are 75% maize and 25% textile waste, Coconut fibre, Cob concrete, sawdust, and Sugar cane and egg tray. From the results shown in Table 6, fine grade sawdust mixed with expansive (from the present study) has the highest NRC value of 0.62 as compared to the other materials from previous studies (75% maize and 25% textile waste with NRC value of 0.28, coconut fibre with NRC value of 0.515, cob concrete with NRC value of 0.285, sawdust with NRC value of 0.05, and sugar cane and ash tray with NRC value of 0.59). The presented results show that, material sample (Fine grade sawdust mixed with expansive clay) from the present study has great NRC potential and should be considered in future NRC experiments.

Table 6 - Comparison of material composition, thickness and noise reduction coefficient between values from literature review and present study.

Material Parameter	Authors					
	Balan and Shivasankaran, 2019	Asdrubali, 2006	Oancea et al., 2018	Tengku Izhar et al., 2015	Kaamin et al., 2019	Present study
Composition of materials	75% maize and 25% textile waste	Coconut fibre	Cob concrete	Sawdust	Sugar cane and egg tray	Fine grade sawdust mixed with expansive
Thickness (mm)	99.5	35	40	30	50	30.1 - 30.6
Noise reduction coefficient	0.28	0.515	0.285	0.05	0.59	0.62

5. Conclusion

This research investigated and analysed the acoustic properties of sawdust, coconut fiber and expansive clay for sound reduction purposes. The results show that fine grade sawdust mixed with expansive clay yielded the highest NRC value of 0.62 at 4 kHz and has a promising NRC potential as compared to the other materials studied.

The materials made with fine grade sawdust, coconut fiber and expansive clay, which are natural materials, have good acoustic properties and therefore could be used as alternative, less expensive, local materials to produce acoustic board panels or tiles with appreciable noise reduction properties. They can be used in industrial halls, conference rooms, studios, offices and other building. Making use of these materials which otherwise are waste products, for sound reduction purposes has high prospects because they are renewable, abundant, cheaper, pose less health risk and safety concern to human health during handling and processing compared to other materials such as Glass fibers, which emit high CO_2 emissions during their manufacturing process. It is recommended that further work be done to look at the binding agent, improving the material, as well as determine the mechanical and thermal properties. Select the best material composition (expansive clay). All the same further research could be conducted to improve the other material compositions.

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