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AGRICULTURE WASTE AS SOUND-ABSORBING MATERIAL: CASE STUDY LIBERIA

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Abstract. In Liberia, agriculture is an important part of the economy and contributes significantly to national income; yet, the enormous amount of agricultural waste produced by agricultural operations and the absence of adequate waste management is negatively affecting the environment. One of the key objectives for improving the living environment is noise reduction. A sound absorber is a tool that may be used to do such. The ability to manage sound has been recognized as one of the essential aspects of a person's comfort. Controlling the room's acoustics is key. Generally, materials utilized for sound attenuation are synthetic fibers like glass wool fiber. Over time, it has been revealed that synthetic fibers are pricey and may be hazardous to the environment and human health. Natural fibers as an alternative to synthetic fiber are therefore receiving more attention. This research presents natural agricultural waste materials as a replacement for conventional sound-absorbing materials as these materials offer the benefits of being inexpensive, lightweight, easily accessible, environmentally friendly, and non-polluting. The waste products from agriculture that can be employed in the realm of noise control include coconut fiber, groundnut shell, and sugarcane fiber.

Keywords: noise pollution, sound absorption, biodegradable material, natural fiber.

Introduction

The primary source of income for more than 60% of Liberia's population is agriculture, which generated 31% of the nation's GDP in 2021. The waste generated by the agriculture industry included 2,115 metric tons of groundnut shell waste from processing and selling groundnuts to retail customers on the street, 49,329 metric tons of waste from coconut harvesting, and 37,715 metric tons of waste from sugarcane fiber used to make the traditional local beverage known as "king-juice" (Edgington, 2019). Farmers in Liberia practice shifting cultivation, agricultural wastes are fed to cattle, and crop residues are burned to clear the field for the preparation of new crops. This method of managing agricultural waste in the agricultural sector in Liberia has a serious negative impact on the environment, affecting air quality, emission of greenhouse gas (GHG), and soil degradation. The escalating negative effects of crop residue burning highlight the necessity of implementing an agricultural waste management strategy that is environmentally responsible and sustainable in order to protect the environment and human health. Managing agricultural waste in an eco-friendly way generates income, which has further economic advantages. The acceptance rate is, however, extremely low in Liberia, despite the fact that the advantages of sustainable agricultural waste management have been extensively studied, understood, and are readily implementable locally (Raza et al., 2022).

Agricultural wastes are carelessly disposed of or burned, which causes air pollution, soil contamination, hazardous gas, and smoke, and the residue may be funneled into water sources, therefore contaminating the water and damaging the lives of aquatic species (Nagendran, 2011). With repair, reuse, and reduction, circular economy seeks to minimize waste and pollution. It also places a strong emphasis on repairing natural systems and developing environments that encourage regeneration. Circular Economy (CE) is an idea that is now being supported by the EU, several national governments, and numerous enterprises all over the world. The new Circular Economy Action Plan (CEAP) was approved by the European Commission in March 2020. It is one of the cornerstones of the European Green Deal, the continent's new plan for sustainable development. The EU's shift to a circular economy will relieve the strain on the planet's natural resources and provide employment and sustainable growth (Ma et al., 2009). The circular economy concept is built on three guiding principles: reduce waste and pollution, circulate goods and resources (at their greatest value), and rejuvenate the environment.

Using cutting-edge technology and successful commercial strategies, Liberia may address the use of agricultural wastes, by-products, and co-products by implementing a circular economy. Such systems are being developed as an alternative to conventional linear manufacturing models. By reducing the use of natural resources and the creation of trash, the CE hopes to create a model that has no overall negative impact on the environment (Toop et al., 2017). The most commonly found agricultural waste products in Liberia are coconut coir fiber, groundnut shells, and sugarcane fiber.

Groundnut fiber. A healthy leguminous crop, groundnut is framed primarily for seed and oil across the world. Groundnut shells (Figure 1) are the byproduct left over when the groundnut seed is removed from the pod. This is a common agro-industrial waste product with a relatively sluggish rate of natural degradation. Furthermore, groundnut shells have several bioactive and functional elements that are advantageous for people. Commercially, it serves as feedstock, food, fertilizer filler, and even a carrier for bio-filters. However, the majority of abandoned groundnut shells are burned or buried, which causes environmental damage (Duc et al., 2019).

Figure 1. Groundnut shell (Duc et al., 2019)

Coconut fiber. Coir, also known as coconut fiber (Figure 2), is a material made from the coconut fruit's outer shell. There are several sources for coir and coir products, and it is utilized in a range of applications across the world, with rope and matting being particularly common uses. Some varieties are grown both organically and conventionally, and some businesses specialize in coir. The layer of tangled fibers between the coconut's inner and outer husks is where coir is derived from. Coconut husks are traditionally soaked to make the fiber expand and loosen so that they may be peeled apart during the processing of coir. Coconut fiber comes in two main varieties: white coir and brown coir. Young coconuts have white fiber, but older coconuts have brown fiber. Because coconut fiber is so strong and can endure both seawater and severe weather, it is frequently used in mats or weaving to stop natural erosion. Additionally, the fiber is used in mattresses as an outer layer and filling.

Figure 2. Coconut fiber (Duc et al., 2019)

Sugarcane fiber. Sugarcane bagasse is another name for sugarcane fiber (Figure 3). It is the fibrous portion of a sugarcane stalk that is still present after the juice has been extracted. This sugarcane portion is frequently thrown away, burned, or utilized as a fuel source for sugar mills. These wastes are often burnt in situ to clear the field for the following crop because they cannot be utilized for cow feeding (without further processing). Utilizing the trash for paper has also been a focus of certain projects. The sugarcane fiber appeared to be made up of small, soft strands that would make for effective sound absorption. The weakness of the soft fibers may be overcome if they are combined with another strong material (Putra et al., 2013).

Figure 3. Sugarcane fiber (Putra et al., 2013)

This study highlights the importance of developing a strategy for managing agricultural waste in an effort to promote the sustainable use of agricultural waste in place of traditional sound-absorbing materials, which have the advantages of being less expensive, lighter, more readily available, environmentally friendly, and non-polluting. Coconut fiber, groundnut shell, and sugarcane fiber are possible agricultural wastes that can be used to reduce noise.

1. Circular economy concept for Agriculture waste management

The circular economy's guiding principles offer an alternate perspective that views trash as the primary source of new resources. In this situation, a wider variety of organic waste might be considered a possible source of biodegradable acoustic materials. When we concentrate on the global scenario, we see that a sizable amount of land is used for agriculture, which produces huge waste streams (Li, 2019). The significant benefit of constructing a "circular economy" system, which converts wasted fibers into usable items with additional value, is the repurposing of trash or byproducts as fresh raw materials for creative and sustainable acoustic materials. Additionally, environmental advantages associated with a reduced demand for disposal and a fewer usage of virgin resources are realized (Rubino et al., 2019).

It is possible to redirect a stream of locally available organic waste from the agricultural system and utilize it as an acoustic material. The creation of methane from such garbage decomposing in landfills, which accounts for 3% of all greenhouse gas emissions, is now the biggest environmental danger from biodegradable trash. Through the use of these natural resources following the principles of the circular economy, this threat may be reduced (Djoumaliisky et al., 2013). The primary reason why natural fiber has attracted so much interest is that it exhibits ecological benefits while performing acoustical qualities. Natural fiber is also affordable, cost-effective, and lightweight (Hosseini Fouladi et al., 2010).

Additionally, organic fiber is abundant renewable, nonabrasive, inexpensive, and poses fewer dangers to human health and safety during handling and processing, making them an excellent base material for absorber materials.

2. Noise pollution effects on living

Similar to other pollutants, noise pollution is a by-product of industry, urbanization, and contemporary civilization. The main causes of noise pollution are industrial and non-industrial, respectively. Large machinery operating at very high speeds and with a lot of noise is included in the list of industrial sources of noise.

Any sound that is unwanted or impairs one's quality of life is considered a source of noise pollution. When there is a lot of noise around, noise pollution happens. When it disrupts daily routines like working, sleeping, or speaking, the sound loses its charm. Due to the fact that we cannot see, smell, or taste it, it is an underappreciated environmental issue. According to the World Health Organization, "Noise must be acknowledged as a serious hazard to human well-being" (Woli et al., 2022). The fact that noise pollution has become a serious environmental problem and causes a variety of health issues, including hearing loss, cardiovascular diseases, and sleep disorders, highlights the need for society to develop affordable, environmentally friendly sound absorption materials to lessen the harm caused by noise pollution in buildings.

WHO defines a noise adverse effect as a short-term or long-term alteration in an organism's morphology and physiology that impairs its ability to function impairs its ability to cope with additional stress, or makes an organism more vulnerable to the negative effects of other environmental influences. The detrimental health consequences of noise pollution on people have been classified into the following categories by WHO (King & Davis, 2003).

- Hearing Impairment;
- Negative Social Behavior and Annoyance;
- Interference with Spoken communication;
- Sleep Disturbances;
- Cardiovascular Disturbances.

Human hearing normally begins at 0 dB in terms of loudness. If you are exposed to sounds that are louder than 85 dB for an extended period, your hearing may suffer damage (Hedaoo & Chavan, 2022). The onset of hearing loss happens faster when the noise is louder, for example, typical breathing is 10 dBA, but the quietest sound a person can hear is 0 decibels. The decibel level of rain is 50, but the decibel level of a typical conversation is 60. At 120 decibels, anything like thunder or yelling in someone's ear would be too loud to be comfortable.

3. Agricultural waste as sound-absorbing materials

Many scientific research has focused on the development of new technologies to control the noise pollution issue.

In general, there are two approaches to reducing noise: active media, where a significant amount of external energy suppresses the noise-generating element; or passive mediums, where sound-absorbing material absorbs the energy of the sound waves. Porous absorbers, membrane absorbers, and resonator absorbers are the three major categories into which sound-absorbing materials may be divided. Depending on their microscopic structures, porous sound absorbing can be classified as cellular, fibrous, or granular. The frictional forces between the cell wall and the air molecules within the porous material cause sound to be converted to heat when sound waves incident normally to the porous sound absorption material (Ma et al., 2009).

The buildup of post-consumer and technical trash is one of our contemporary urbanized society's most difficult and significant issues. Their reuse and reintroduction to the market might be a good solution to address environmental issues by providing affordable recycled materials. Secondary materials with strong thermal and sound absorption qualities, such as groundnut shell, coconut fiber, and sugarcane fiber, offer an alternative to traditional materials for real-world application in building noise control (Djoumaliisky et al., 2013).

In the past, costly, non-biodegradable materials like polymer fibers and glass wool, which have negative effects on human health and the environment, were used to create noise-absorbing materials. Methane, nitrous oxide, and carbon dioxide are released during the manufacture of synthetic fibers and are harmful to human health. Synthetic fibers are also not skin-friendly and can be uncomfortable to handle and process. Investigations revealed that artificial fibers can irritate the skin and be harmful to human health if breathed because they can lodge in the lung's alveoli. As a result, interest in the introduction of natural fiber has increased during the past few years. Natural fiber has received a lot of interest mostly because it has ecological benefits while also having acoustical qualities. Natural fibers are also affordable, renewable, and lightweight (Ma et al., 2009).

Numerous studies have examined the relationship between the acoustic behavior of natural fiber and processing factors such as granulometry, binder type and concentration, compaction ratio, and final thickness. This has opened the door for further scientific investigation into the development of natural biodegradable fiber acoustic sound-absorbing panels. According to the results of these tests, natural biodegradable material can be used in place of conventional sound-absorbing materials.

Given that they are low-density materials and produce relatively lightweight composites with strong specific characteristics, natural fibers have a number of favorable qualities that make them an excellent choice for composite reinforcing. In comparison to manufactured fibers like glass, nylon, carbon, etc., natural agricultural biodegradable materials also provide considerable economic savings and processing benefits (Yuhazri & Sihambing, 2010).

Acoustic absorbers made of natural materials are consequently appealing because of their biodegradability and sustainability in order to help the "Green" environmental movement. As an alternative, natural fibers derived from agricultural wastes, such as coconut fiber, groundnut shell, and sugarcane fiber, can be utilized as affordable, biodegradable, and recyclable sound absorption materials. Researchers have struggled to create soundproofing materials composed of natural fiber that are technique improved. With the use of coconut fiber, groundnut shell, sugarcane fiber, etc., which act as non-abrasive, porous, excellent insulators, hygroscopic, and flammable materials for structures, the current focus is on developing a cheap, renewable, and biodegradable soundproofing material.

The design and development of sound-absorbing materials from natural agricultural waste fiber are loosely based on an organized collection of concepts drawn from scientific domains, including new fields and semi-scientific conceptions. These sources cover, making biodegradable building material from agriculture residue (Li, 2019), noise control using coconut coir fiber sound absorber with porous layer backing and perforated panel (Zulkifli et al., 2010), composite eco-friendly sound absorbing materials (Rubino et al., 2019), utilizing sugarcane wasted fiber as a sustainable acoustic absorber (Putra et al., 2013), multilayered sound absorbing panels based on waste materials (Djoumaliisky et al., 2013).

Experiments were performed on three separate samples of groundnut shell materials with different thicknesses (10 mm, 20 mm, and 30 mm) and the inclusion of gaps (Malawade et al., 2021). A transfer frequency response method was used to test the sound absorption coefficient for several frequency ranges between 100 and 4000 Hz Figure 4 shows the graph of sound absorption coefficient versus frequency for three different thickness samples.

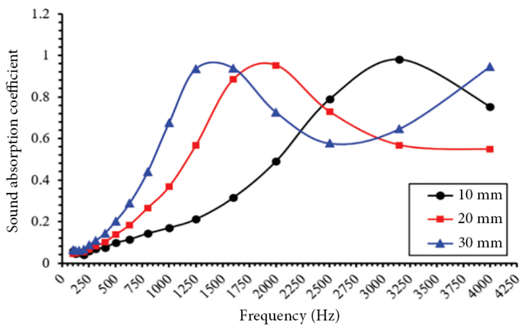

Figure 4. Characteristics of normal sound absorption coefficient of three samples of groundnut shell with different thickness (Malawade et al., 2021)

Impedance tube measurements were made for coconut fiber with and without backing, fiber with a porous layer backing, and samples with a thickness of 10 and 20 mm at low and high frequencies (50–5000 Hz) (Zulkifli et al., 2010). The noise absorption coefficient for samples with a 20 mm thickness reaches its greatest value in the 3680–3860 Hz frequency range, as shown in Figure 5. At frequency 3784 Hz, the peak noise absorption value is around 0.83. The Noise Absorption Coefficient (NAC)

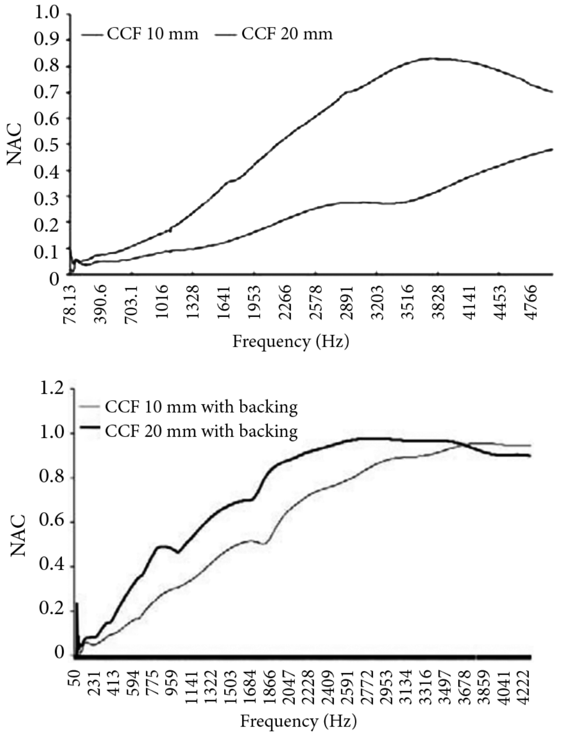

Figure 5. Noise absorption coefficient coconut fiber with and without porous layer (Zulkifli et al., 2010)

maximum value for samples with a thickness of 10 mm is around 0.39 at a frequency of 5000 Hz.

Using the two-microphone transfer function method in accordance with ISO 10534-2:200, the sound absorption coefficient of sugarcane fiber (denoted as α) was measured in an impedance tube (Putra et al., 2013). Figure 6 compares the acoustic absorption of 1 gram of waste fiber from sugarcane using polyester and polyurethane. The result shows that the performance of sound absorption is not considerably impacted by the binder composition (up to 40%). For frequencies above 3.5 kHz, good performance of the sound absorption coefficient of more than 0.5 (>0.5) is demonstrated. For both varieties of binders, the absorption coefficient rises until it reaches the value of 4.5 kHz at 0.78.

An impedance tube was used to evaluate the sound absorption coefficient of two agricultural wastes, palm leaves, and wheat straw fibers according to ISO 10534-2-200 (Ali et al., 2022). For hybrid sample boards 6 to 10 with diameters (40 mm, 35 mm, 47 mm, 26 mm & 29 mm), the amount of sound energy absorbed was calculated from the difference in sound pressure measured between two microphones. The hybrid board samples sound absorption coefficients are presented in Figure 7. Sample boards 6, 7, 8, and 10 have better sound absorption coefficients greater than 0.5 above 600 Hz.

Board 9 has excellent sound characterization, in contrast, above 700 Hz, where the sound absorption coefficient

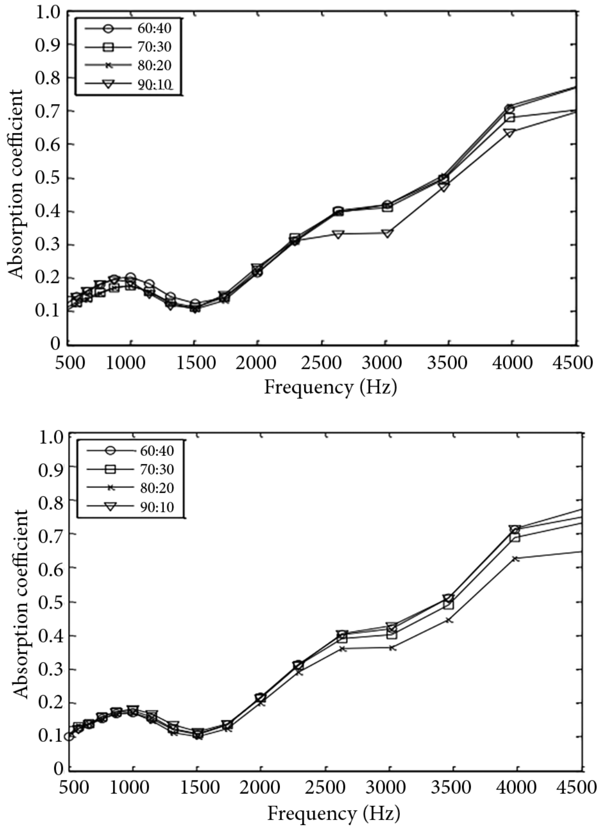

Figure 6. Measured absorption coefficient of gram sugarcane fibers using polyurethane (on top) and polyester (below) (Putra et al., 2013)

is larger than 0.5 and the sound absorption bell curve peaks at roughly 0.95 Hz. Boards, like numbers 6, 7, and 10, had bell forms and, at frequencies of 100 Hz, 900 Hz, and 950 Hz, respectively, have sound absorption values of about 0.9 and 0.8. The good acoustic qualities of the lab-made boards are confirmed by Figure 7, especially for all of the boards above 600 Hz (Ali et al., 2022).

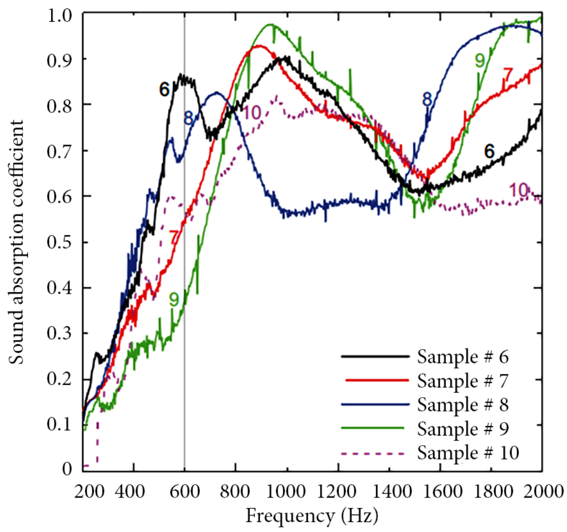

Figure 7. Sound absorption coefficient of hybrid boards specimens (Ali et al., 2022)

While some of these studies have contributed significantly to the sustainable science of using agricultural waste, more research is necessary to develop an environmentally friendly approach to using agricultural waste given the rise in agricultural waste and its detrimental effects on the environment.

Conclusions

By establishing a circular economy system, the reuse of waste agricultural biodegradable materials as sustainable acoustic sound absorbent panels provides a means of waste management and usage.

Furthermore, a lot of young researchers are inspired to come up with creative ways to transform these fiber materials into useful value-added goods by the abundance of local natural materials in Africa as a result of the continent's extensive agricultural activity, which produces natural biodegradable material with sound absorption and thermal insulation.

The utilization of agricultural waste to develop eco-friendly sound-absorbing panels is also a circular economy strategy to ensure proper waste management and lessen the volume of methane contribution from biodegradable waste toward greenhouse gas emissions. This also presents reasonable economic benefits to the agricultural sector by implementing the circular economy guidelines.

The acoustic performance of a sugarcane fiber absorber with a thickness of ½ inch is comparable to that of commercial sound insulators, which have an average absorption coefficient of 0.65 at frequencies between 1.2 and 4.5 kHz. Additionally, hybrid fiberboards made of palm leaves and wheat straw fiber have shown good sound absorption above 0.6 for frequencies between 900 Hz and 2000 Hz.

Dedication

This study is in honor of my father, Mr. Edward Emmanuel Gboe. He has given up lucrative overseas positions to serve his country because he is so passionate about changing Liberia. You have been a source of motivation, encouragement, and direction. You have taught me to be distinct, resolute, confident, and to always continue. I'm very grateful and proud to call you father.

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ŽEMĖS ŪKIO ATLIEKŲ NAUDOJIMAS KURIANT GARSĄ SUGERIANČIAS MEDŽIAGAS: LIBERIJOS ATVEJO ANALIZĖ

N. A. GBOE, R. GRUBLIAUSKAS

Santrauka. Liberijoje žemės ūkis yra svarbi ekonomikos dalis, labai prisidedanti prie nacionalinių pajamų. Deja, susidarantis didžiulis žemės ūkio atliekų kiekis bei tinkamo atliekų tvarkymo sistemos nebuvimas neigiamai veikia aplinką. Vienas pagrindinių gyvenimo aplinkos gerinimo tikslų – atliekų antrinis panaudojimas, pavyzdžiui, kuriant triukšmo mažinimo priemones. Gebėjimas valdyti garsą buvo pripažintas vienu iš esminių komfortiškų žmogaus gyvenimo sąlygų. Paprastai garsui slopinti naudojamos medžiagos yra sintetiniai pluoštai, tokie kaip stiklo vatos pluoštas. Laikui bėgant paaiškėjo, kad sintetiniai pluoštai yra brangūs ir gali būti pavojingi aplinkai bei žmonių sveikatai. Todėl natūralus pluoštas kaip sintetinio pluošto alternatyva sulaukia daugiau dėmesio. Šiame moksliniame tyrime natūralios žemės ūkio atliekos (kokoso pluoštas, žemės riešutų kevalai, cukranendrių pluoštas ir kt.) pristatomos kaip įprastinių garsą sugeriančių medžiagų pakaitalas, nes šios medžiagos yra nebrangios, lengvos, plačiai prieinamos ir nekenksmingos aplinkai.

Reikšminiai žodžiai: triukšmo tarša, garso sugertis, biologiškai skaidžios medžiagos, natūralus pluoštas.