J. Int. Environmental Application & Science, Vol. 17(2): 56-62 (2022)
Research Paper

Evaluation of Noise Attenuation Property of Acoustic Panel made from Recycled water Sachets

Owhor Sampson Chisa[1], Joel Daniel Amine[2], Azodo Adinife Patrick[1],*,

[1]Department of Mechanical Engineering, Federal University Wukari, Taraba State, Nigeria; [2]Department of Mechanical Engineering, Federal University of Agriculture, Makurdi, Benue State, Nigeria

Received June 6, 2022; Accepted July 20, 2022

Abstract: Noise and waste generally render our environment unfriendly and difficult to inhabit. There is a need to create measures for a healthy living environment. This research work evaluated the sound absorption property of an acoustic panel produced from waste Packaged in Low-Density Polyethylene (LDPE) materials. The waste recycling management approach from LDPE waste of water sachet materials was adopted for an acoustic panel the production by the casting method. Sound absorption coefficient evaluation of the produced acoustic panel of recycled LDPE wastes of water sachets materials gave an α value of 0.73, considered an efficient sound wave energy absorber on the scale of 0.0 – 1.0 sound absorption coefficient of materials. This study recommends a waste recycling management approach for treating LDPE material since the produced panel from the LDPE waste reduced transmitted noise and served as an effective solid waste management technique in the environment.

Keywords: *water sachets, waste recycle, acoustic panel, sound absorption**,** LDPE, material waste*

Introduction

Sound is produced from vibrating bodies propagated through the air by the displacement of air molecules (Anyakoha, 2015). Sound, irrespective of the source, is subjectively or/and objectively asserted as a pollutant in the environment when the intensity is beyond a specific limit (as cited in Azodo *et al*., 2019). Even though noise pollution is transient, it is regarded as one of the major pollutions with severe environmental repercussions. It does not build up in the environment, but it has a long-term impact on people's life and property values. Noise pollution plays a vital role in the degradation of the environment, and quality of life deterioration and can lead to changes in the physical, psychological, physiological, and social functioning of the human system, either short or long-term (Goines and Hagler, 2007), as such need to be controlled (as cited in Cao et al., 2018). Exposure to noise over time, can lead to different health issues, including sleep disturbances, hearing loss, and cardiovascular illness (Azodo & Adejuyigbe, 2013). It, therefore, becomes imperative to develop materials that are both cost-effective and environmentally friendly to reduce noise pollution.

Noise pollution management approaches include source and transmission path control, and the use of protective equipment. In these techniques, sound insulation materials or absorbers are employed to prevent sound entry or exit an enclosed space (soundproofing) or to make acoustic corrections to spaces by changing the reverberation time. Studies categorized sound absorption materials according to their noise amelioration mechanisms as resonant and porous materials (Zhao et al., 2016; Zhai *et al.,* 2018). These materials release the harmful effect of noise hazard when sound waves strike on the porous materials through reflection, absorption, and transmission of the sound energy (Cao et al., 2018). Arenas and Crocker (2010) added that the sound absorption properties of sound absorption materials are higher than the reflection property. Porous sound-absorbing materials used either for sound or thermal energy reduction is produced in rolls or slabs shapes. They are made mostly from fibrous materials and have different acoustic properties. Fibrous materials are either natural or synthetic are composed of continuous filaments set or pores substantially efficient for absorbing sound energy (Arenas and Crocker, 2010). Minerals and polymers based synthetic fibrous materials used for sound absorption are made from petrochemical sources by high-temperature extrusion and industrial processes. However, studies observed significant footprints and cost as the pitfalls of this process (Arenas and Crocker, 2010), hence the need for an alternative.

**Corresponding: E-Mail: azodopat@gmail.com; Tel: 08139513021, Fax: 08139513021*

The acoustic energy absorption of porous materials is by friction. As air moves into the pores of the sound-absorbing materials, rather than reflecting the sound energy into the source space, it dissipates the sound energy as heat (Crocker and Arenas, 2007; Arenas and Crocker, 2010). The effectiveness of sound-absorbing materials is when they are used in conjunction with barriers inside enclosures (Crocker & Arenas, 2007). The sound pressure levels difference inside and outside a closed space depends on the transmission loss of the enclosure panels and the acoustic absorption within the enclosure. The various locations where sound-absorbing materials are applicable for noise control are at the source of noise, transmission path and close to a receiver (Arenas and Crocker, 2010).

The quantification of the ability of porous sound absorption materials to dissipate sound is determined by assessing the sound absorption coefficient of the material (α). The sound absorption coefficient of a material (α), for sound, dissipates or an absorption phenomenon is the ratio of absorbed sound energy to the total incident sound energy. The expression of the sound absorption coefficient is in a single value format ranging from 0.0 - 1.0 that describes the average sound absorption performance of a material. An average sound absorption coefficient of 0.0 indicates the object does not attenuate mid-frequency sounds but reflects sound energy. However, this is practically impossible since very thick concrete walls attenuate sound with an average sound absorption coefficient of 0.01. Conversely, an average sound absorption coefficient of 1.0 indicates that the material provides an acoustic surface area equivalent to its physical two-dimensional surfaces.

Synthetic fibrous materials are one of the major solid waste materials in Nigeria. The petrochemical-derived product, which is packaged in Low-Density Polyethylene (LDPE) material, is widely utilized for several reasons in Nigeria, including the packing of pure drinking water. Ademiluyi (2007) attributed water packaging using the LDPE to the economic situation of the country and the inexpensive cost of the material. LDPE-based water packaging is now used in practically every community across the country. The expanding population and increased preference for packaged commodities are worsening the negative environmental impacts of these polyethylene materials through water consumption in these LDPE materials and improper disposal of the waste. According to Ademiluyi (2007), the contribution of LDPE wastewater sachets considerably contributes to solid waste management difficulties in the national concern since LDPE has a very high low rate of degradation. Edoga *et al.* (2008) noted that about 70 per cent of Nigerian adult's drink at least a sachet of pure water per day, resulting in about 50 to 60 million used water sachets disposed of daily across the country. Some of the collected wastes end up being combusted, thereby adding to the air pollution. Another environmental solid waste challenge attributed to these packaged in low-density polyethylene materials is their non-biodegradable nature. The LDPE in the soil prevents water from getting to the root of the plants. It also restricts the stretching of the plant root. Some of it hinders the exchange of gases for respiration by plants and animals in the water body. Some of these wastes litter the streets find their way into drains, trenches, and canals, thereby clogging drains and hindering the free flow of water and consequently leading to flooding. Given the hazards of the improper disposal of packaged in low-density polyethylene materials wastes, the need then arises for an alternative means to manage the waste. This study considered recovering LDPE material wastes and turning them into a useable product that can re-enter the manufacturing chains and contribute to a cleaner environment through a waste recycling management approach. Therefore, this research work evaluated the sound absorption property of an acoustic panel produced from recycled waste LDPE of sachets water material.

Materials and Method

Figure 1 show the materials used in production of the acoustic panel from recycled water and noise attenuation testing effect. The raw material used for the production of the acoustic panel was a LDPE waste of water sachets. Firewood was the heat source for the heating and melting of the LDPE waste of water sachets to a molten state. A steel pot was used for melting the water sachets because of its ability to withstand high temperatures. During the melting process, a stirrer was utilized to agitate the heated water sachets inside the pot, allowing for homogeneity of the sachets and preventing lumps from forming due to heat. The stirrer mixed the sachets during the heating process to the melting process to a molten state where the flow is uniform, and no lumps were present inside the molten material. During this process, stirring the sachets keeps them from clinging to the pot's walls and burning. A predesigned wooden mould of 2 × 4 feet and 1.5 inches dimension with cardboard placed in its interior and screw at the four edges of the mould for easy removal serve as the mould design to use for the casting of the molten material to produce an acoustic panel. The mould was placed at a flat surface and slammed to the ground for even spreading of the molten material during casting. The Bluetooth speaker operated through a mobile phone provided the required attenuation. The sound intensity was measured using two digital sound level meters (model LU0115) with a dynamic range of 30 to 130 decibels and a frequency range of 31.5 Hz to 8 kHz. The sound level meters have frequency weighing C and A mode for responding to machine or human senses during the monitoring purposes. The methods involved in this study were of two stages; production of the acoustic panel and sound absorption coefficient (SAC) test (Figure 2).

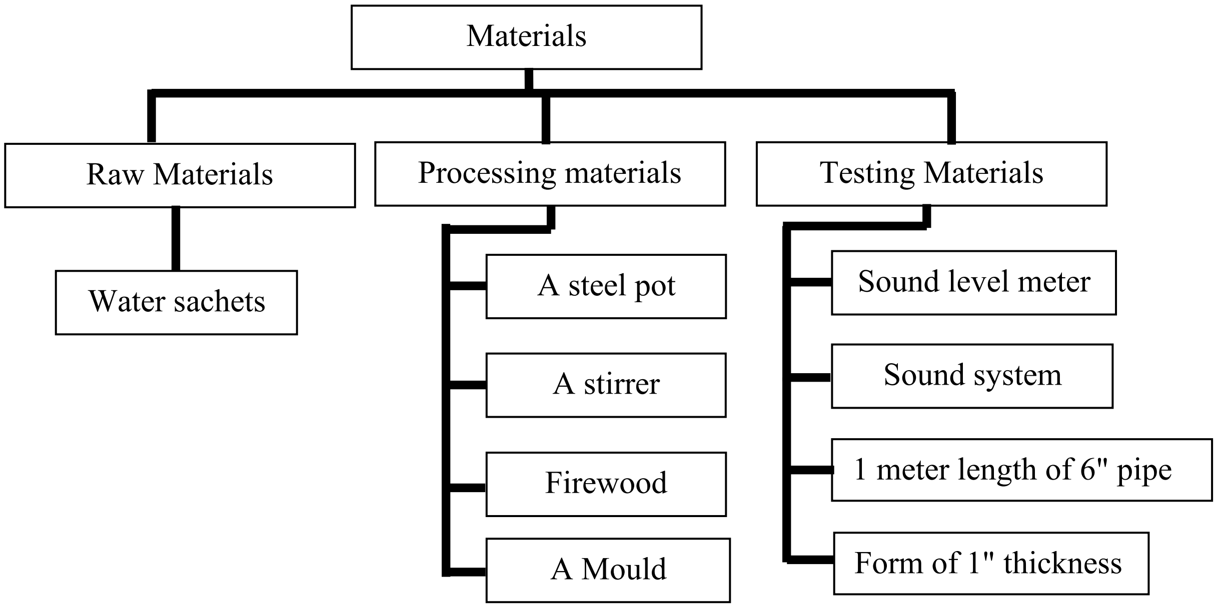

Figure 1. Graphical representation of the materials used in this study.

Sequence followed in the production of the acoustic panel

Collection of raw material

The LDPE waste of water sachets used for this study was handpicked from trenches, drainages, streets, dump sites and eateries around the Makurdi metropolis, Benue state. The LDPE waste water sachets were collected in large quantities and placed inside bags and sacks before being gathered into 750kg capacity bags.

Sorting and washing of the water sachets

Sorting involves the separation of the water sachets into different categories due to their stains and neatness by manual process. Detergent and water were used in washing the already sorted water sachets materials to remove impurities and get rid of contaminants such as adhesives and dirt from the LDPE waste of water sachets to allow for easy and proper melting of the material.

Drying of the water sachets

After washing the water sachets, they were spread in a clean environment free from dirt and sun-dried. The sachets were shredded to make it easy and faster for the drying process to be more efficient. The melting process is accelerated by drying the LDPE waste of water sachet materials for effective melting.

Melting of the water sachets

An empty steel pot was heated for five minutes to dry it out and distribute the heat evenly. The shredded LDPE waste of water sachet materials was gradually and continuously added to the heated steel pot until it was fluidized. The melted water sachets inside the steel pot for stirred for agitating during the melting process to allow for uniformity of the sachets and avoid forming lumps.

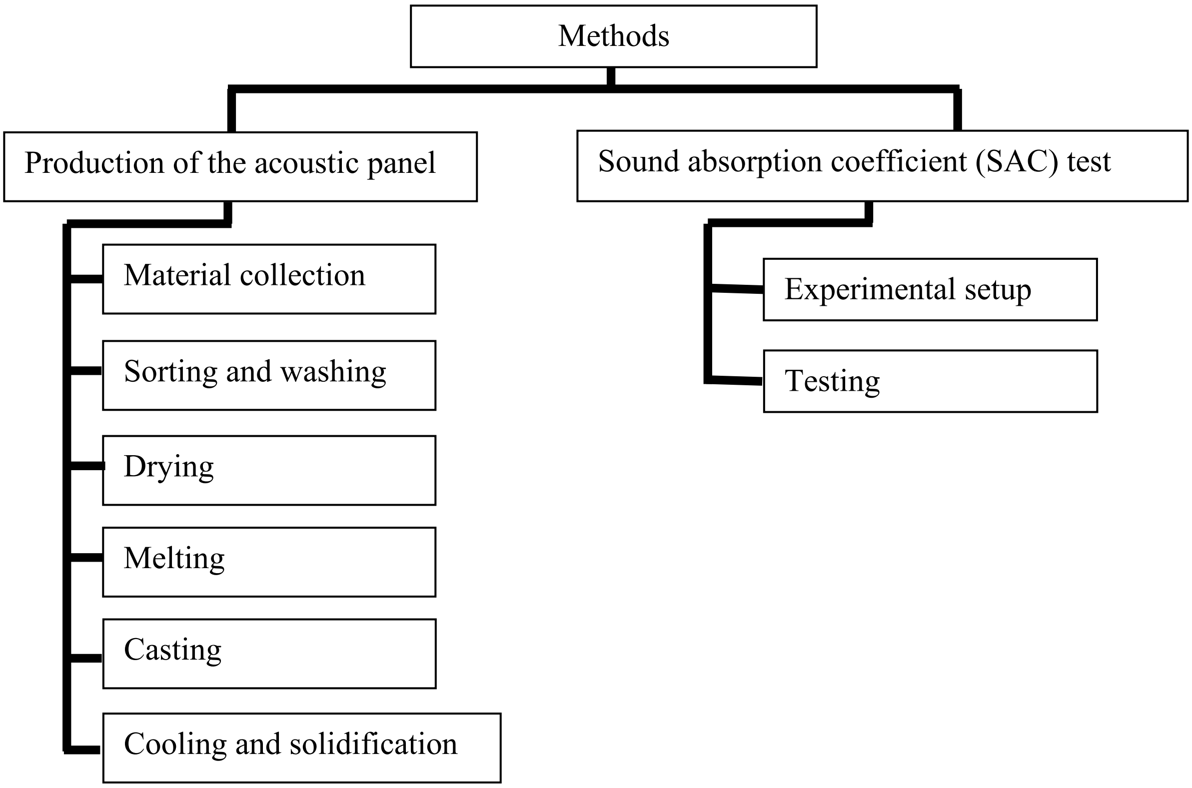

Figure 2. Graphical representation of the research methods in this study.

Casting of the molten water sachet material

The hot molten water sachet material was poured into a prepared rectangular mould rectangular open-top mould. During the casting of the molten LDPE waste of water sachet materials, it was ensured that the molten material spread evenly in the mould and escapes bubbles that can cause a crack in the acoustic panel. The molten material pouring in the mould was neither too fast nor not too slow.

Cooling and solidification

After the casting of the molten material, it was allowed to cool at room temperature and solidifies. The cooling started at the wall of the mould to the centre of the mould before complete solidification took place. The solidified LDPE waste of water sachet materials is the need an acoustic panel.

Experimental setup for sound absorption coefficient (SAC) test

The panel produced was tested for noise absorption property. The experimental setup for sound absorption coefficient (SAC) test set up is as presented in Figure 3. The centre of the 1-meter length of the 6 inches pipe was cut open with proper measurement to fit the thickness of the produced LDPE material waste panel. Two holes were bored on the left and the right side of the pipe appropriate for the noise level meters. The 1-inch foam was used to wrap the entire length of the pipe to serves as sound insulators. The sound meters were set to dBC frequency weighting and slow mode for slow weighting time (1s each reading), which was positioned at the top of either side of the pipe at the hole bored for them. A Bluetooth speaker was placed in the side pipe labeled A and firmly closed. The produced acoustic panel sample was placed in the middle of the pipe in the groove cut. The other side of the pipe labeled B was also closed with foam to avoid sound going out of the pipe (Figure 3).

Music was played through the speaker using a mobile phone. The noise was created inside the pipe by the Bluetooth speaker conveyed a sound wave to the acoustic panel. At the end of one minute, the sound level measurements on the sound level meters at both ends of the pipe were recorded concurrently. A total of ten readings were taken at intervals of one minute with different volumes and sounds to ascertain the level of sound absorption of the acoustic panel. The second and third noise absorption tests followed the same other as the first using different soundtracks. The sound level for the second and third noise absorption tests recording were at intervals of two and three minutes, respectively.

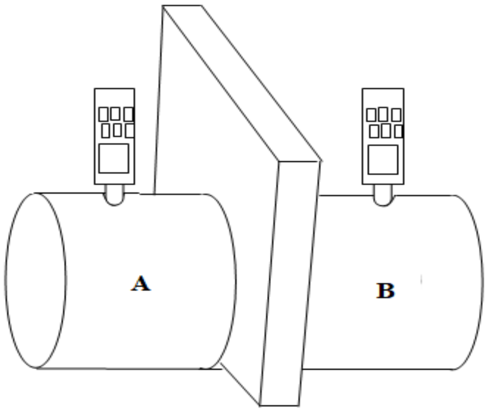

Figure 3. Experimental setup for sound absorption coefficient (SAC) test

Evaluation of the sound absorption coefficient

Sound absorption coefficient used to evaluate the sound absorption coefficient of materials was the ratio of the absorbed energy to the incident energy and is represented by α (Cao et al., 2018).

$$\alpha = \frac{E_a}{E_i} \quad (1)$$

Where
α = sound absorption coefficient of a material.
E_a = is the sound energy absorbed by the material.
E_i = is the sound energy spread and reaching the surface of a material.

Results and Discussions

The vertical and the horizontal views of the acoustic panel produced are presented in Figure 5. The acoustic panel produced was rectangular. The dimension of the acoustic panel produce was 4 feet in length, 2 feet in width and 1.5 inches in thickness.

Vertical view

Horizontal view

Figure 5. The acoustic panel produced from wastewater sachets

The sound absorption test carried out using the sound level meter at different sound volumes are presented in Table 1. Table 1 shows the sound intensity values measured with two sound level meters simultaneously from both sides of the pipe materials. Incident sound from the Bluetooth speaker and sound intensity absorbed by the acoustic panel developed for this research work and tested using three different soundtracks. The sound from the speaker is the sound energy spread and reaching the surface of a material (E_i) while E_a represented the sound energy absorbed by the material. The sound absorption coefficient obtained using equation (1) for three categories of noise attenuation tests at ten different volume settings were 0.76, 0.74, and 0.70 dB with an average value of 0.73dB. The value 0.73dB is recorded as the sound absorption coefficient of the acoustic panel. The average sound absorption coefficient of 0.73dB obtained implies that the mean sound absorption performance of acoustic panel produced from the recycled LDPE waste of water sachet materials from the range 0.0 - 1.0, therefore consider a good sound absorber of sound wave energy. Any material that can absorb the acoustic energy entirely has a sound absorption coefficient of (α) = 1. It means that all of the sound waves were absorbed by the material panel. When compared to the sound absorption coefficient of other materials, the efficacy of the generated acoustic panel fell into the category of an excellent sound absorber. Polyurethane foam, flexible, has a sound absorption coefficient of 0.95, slag wool or glass-silk, 50mm, has an absorption coefficient of 0.8-0.95, and acoustic tiles, 0.4-0.8. Low absorption rate are not good sound absorbers like concrete block, coarse has an absorption coefficient of 0.3 - 0.4, concrete block, painted has 0.1 - 0.2, hardwood has an absorption coefficient of 0.3 and glass, an ordinary window has from 0.1 - 0.2.

Table 1. Incident sound intensity from the speaker and sound intensity absorbed by the acoustic panel

Volume settings	**Experimental tests**								
	Sound intensity from the sound system speaker (E_i)			**Sound energy absorbed by the material (E_a)**			**Total sound absorbed**		
	1ST	2ND	3RD	1ST	2ND	3RD	1ST	2ND	3RD
1	126	119	124	97	84	87	29	35	37
2	123	127	118	89	100	83	34	27	35
3	105	127	127	79	96	89	26	31	38
4	120	126	125	90	100	88	30	26	37
5	103	125	115	77	88	81	26	37	34
6	118	124	121	82	94	79	36	30	42
7	121	116	126	88	78	89	33	38	37
8	111	121	103	91	87	74	20	34	29
9	124	111	116	90	91	82	34	20	34
10	123	126	124	96	93	87	76	33	37

Conclusion and recommendations

Polyethylene products, especially LDPE waste of water sachet materials, after usage are discarded. As such, they end up forming a substantial proportion of the solid waste component in our environment because of their cumulative effect and inability to undergo easy biodegradation. In this work, the production of an acoustic panel from recycled water sachets was conducted. The sound absorption coefficient of the produced acoustic panel was 0.73 dB which made it a good sound-absorbing material. As a result, this study recommends that LDPE wastewater sachets be separated and properly disposed of in dump bins and bags, where they can be collected and recycled into a beneficial product such as an acoustic panel.

References

Ademiluyi FL, (2007) Business competencies needed for effective entrepreneurship as perceived by fresh graduates. *Business Education Journal, 6*(1), 235-246. https://files.eric.ed.gov/fulltext/EJ1309850.pdf

Anyakoha, M.W. 2015. *New school physics for senior secondary schools*. Fourth Edition, Africana First Publishers PLC, Nigeria

Arenas, J.P., and Crocker, M.J. 2010. Recent trends in porous sound-absorbing materials. *Sound and vibration, 44*(7), 12-18. https://scirp.org/reference/referencespapers.aspx?referenceid=1815229

Azodo A.P. and Adejuyigbe S.B. 2013. Examination of noise pollution from generators on Obantoko residents. *Asian Journal of Engineering, Science and Technology. 3*(1), 31- 41. https://www.academia.edu/8073498/Examination_of_Noise_Pollution_from_Generators_on_Obantoko_Residents

Azodo A.P. and Omokaro, I. 2018. Acoustic safety observances and hazard potential in personal audio systems; effect of background noise on users maximum output levels. *Journal of Health and Environmental Studies, 2*(1) 251 – 258. https://www.academia.edu/41281449/

Acoustic_Safety_Observances_and_Hazard_Potential_in_Personal_Audio_Systems_Effect_of_Background_Noise_on_Users_Maximum_Output_Levels

Azodo, A.P., Onwubalili, C. and Mezue, T.C. 2018. Experimental investigation of industrial noise intrusion in the residential areas as an effect of settlement pattern and land use planning. *Mindanao Journal of Science and Technology, 17*, 18 – 30. https://mjst.ustp.edu.ph/index.php/mjst/article/view/256

Crocker, M.J., and Arenas, J.P. 2007. *Use of sound-absorbing materials*. Handbook of Noise and Vibration Control (M.J. Crocker, Ed.), John Wiley and Sons, New York. http://dx.doi.org/10.1002/9780470209707.ch57

Edoga, M.O., Onyeji, L.I., and Oguntosin, O.O. 2008. Achieving vision 20: 2020 through waste produce candle. *Journal of Engineering and Applied Sciences, 3*(8), 642-646. http://docsdrive.com/pdfs/medwelljournals/jeasci/2008/642-646.pdf

Hagler, L., and Goiner, L. 2007. Noise pollution: A modern plague. *Southern Medical Journal, 100*(3), 287-294. https://pubmed.ncbi.nlm.nih.gov/17396733/

Zhai W, Yu, X., Song, X., Ang, L.Y.L., Cui, F., Lee, H.P., and Li, T. 2018. Microstructure-based experimental and numerical investigations on the sound absorption property of open-cell metallic foams manufactured by a template replication technique. *Materials and Design, 137*, 108-116. https://www.sciencedirect.com/science/article/pii/S0264127516302246

Zhao XD., Yu, Y.J., and Wu, Y.J. 2016. Improving low-frequency sound absorption of micro-perforated panel absorbers by using mechanical impedance plate combined with Helmholtz resonators. *Applied Acoustics, 114*, 92-98. https://www.infona.pl/licenses/list?documentId=bwmeta1.element.elsevier-29a83c5b-a856-39e6-a690-5a61d98f63bd