# Development of a Sound Muffler Cabinet for Petrol Generators Using Local Acoustic Materials

ONWE, DAVID NWABUEZE[1], OKAFOR VICTOR CHIJIOKE[2], ANEKE SAMUEL CHIKEZIE[3]

*[1]Department of Agricultural and Food Engineering, Faculty of Engineering, University of Uyo, Uyo, Akwa Ibom State, Nigeria.*

*[2]Department of Agricultural and Bio-resources Engineering, School of Engineering and Engineering Technology, Federal University of Technology Owerri (FUTO), Nigeria*

*[3]Department of Computer Engineering, Faculty of Engineering, University of Uyo, Uyo, Akwa Ibom State, Nigeria.*

***Abstract - Irregular and epileptic power supply in Nigerian, Africa and some other parts of the globe has made electric power generators the primary source of power for domestic and commercial purposes in such places. These generators produce noise pollution to the environment. Thus, a petrol generator muffler cabinet was produced to curb noise pollution. The muffler cabinet was designed and fabricated using a 2 mm mild steel and iron brazing to make it sturdy. The inner dimensions were 1 m × 1 m × 1 m. The outer dimensions were 1.12 m × 1.12 m × 1.12 m, creating a hollow of 0.12 m for the acoustic materials. The cabinet was provided with door, air vent and suction fan. Sawdust, sand and foam were used as acoustic materials to lag the cabinet. Five petrol generators of varying capacities 2, 3, 6, 10 and 14 kVA respectively were used for the experiment. A sound level meter was used to measure the sound from the generators at varying distances of 0, 5, 10, 15 and 20 m respectively. Two-way Analysis of Variance (ANOVA) was used to test the difference between generator sound inside and outside the cabinet at (α = 0.05). The sound intensity from the generator when place outside ranged from 60.9-91.8 dB. The sawdust as acoustic material was most efficient as it reduced the noise intensity to 47-80.1 dB, followed by foam which reduced the noise intensity to 48.5-73.8 dB. Sand as acoustic material reduced the noise intensity to 52.1-78.7 dB. The noise intensity of all the generators generally decreased as distance from the generators increased. There was a significant difference at (α = 0.05) between the noise level from the from generators when placed outside and when placed inside the cabinet with the three different acoustic materials respectively. All three lagging materials used as acoustic materials for the noise muffler cabinet reduced the noise levels from the various generators below 85 dB which is the threshold beyond which sound is considered potentially dangerous.***

***Indexed Terms- Electricity, Electric generators, Noise, Noise Reduction***

## I. INTRODUCTION

Mechanical power required in supplying most of global energy needed for global industrialization and motorization is supplied by fossil fuels (Onwe and Bamgboye, 2022). Most of the earth's energy comes in form of mechanical or electrical energy. The socio-economic development and the standard of living of any nation is a function of their energy generation capacity. The development and standard of living of developed nations is a function of their per capita power consumption. This is evident with countries such as the United States of America, Australia, Germany and Japan with high per capita power consumption and countries like Bangladesh, Cambodia, Nigeria and Myanmar with low per capita power consumption (Etukudor *et al.*, 2015). Nigeria as a country is highly blessed with abundant natural resources required for electricity generation. These resources include crude oil, coal, tar sands, natural gas, wind, hydro, solar radiation, numerous biofuel sources, as well as other sources of energy such as niobium and nuclear (Ibitoye and Adenikinju, 2007; Oseni, 2012). According to Fakehinde *et al.* 2019, only 45% of Nigerians have access to electricity supply. This access is both unstable and unreliable

(Babatunde *et al.,* 2019; Nweke *et al.,* 2016) due to inadequate generation and incessant collapse of grid. Thus, to satisfy their energy need, Nigerians have resulted to the use of gasoline and diesel generators to augment for their power needs both for domestic and commercial purposes. This, development is accompanied with both economic and environmental consequences. Noise pollution is one of the factors listed amongst the major disadvantages of internal combustion (IC) engines (Kakadiya, *et al.*, 2007) in addition to low power production efficiency, high heat loss and air pollution. The pressure wave that results from alternating air pressure pulses of high and low pressure is known as sound. Noise is defined as an undesirable or an unwanted sound. Pressure waves are produced in the IC engine by the recurrent opening and closing of the exhaust valve. As a result, the sound wave is created by the high pressure of exhaust gases being transformed to low pressure through pressure pulses. These pressure pulses form the noise that is produced from the engine. Electricity generators are normally accompanied with vibrations and noise, which poses environmental, social and health challenges to man and animal (Willis and Scott, 2000). Vibration and noise from electricity generators is a global problem. However, the Nigerian experience is enormous as a result of irregular and epileptic power supply, making electric power generators the primary source of power for domestic and commercial purposes (Ibitoye and Adenikinju, 2007; Yesufu *et al.*, 2013; Azodo, 2014). According to Okoro (2014), there has been a steady increase in the rate of importation of electric power generator over the years. Adeyemo (2012) estimated the importation of about 60 million generators of varying sizes in Nigeria, used massively in offices, business premises, homes, schools, churches and more. The intense cases are shopping or commercial centers, where several units are operating simultaneously to run business. According to Amos *et al.* 2018, Sound is a product an object vibrating in open air and emitting pressure waves into the air. The decibel (dB) scale defines the level of sound from 80 to 100 dB as (very loud), 100 to 125 dB (uncomfortable) and 140 dB (threshold of pain). Unmuffled gasoline and diesel engines produces exhaust noise in the range of 85-100 and 100-125 decibel (dB) respectively. The human ear can tolerate a noise up to 80-100 dB, however, noise above 100 dB creates pain and discomfort, and can also lead to deafness (Rajendra *et al,* 2015). The level of sound that is healthy for the human ear ranges from 0 to about 140 dB. 0 dB being a serene level for the ear, as the sound level exceeds 100 dB, it will become sensationally loud to the ear, and about the threshold of 140 dB the sound level will become painful noise to the ear. The sound or noise level of 80 dB is averagely normal for the human ear (Okoro, 2014). According to the Nigeria Environmental Protection Agency (EPA), the acceptable threshold of noise level is 70-75 dB, at above 90 dB hearing impairment sets in (Okoro, 2014). Protracted exposure to excessive sound above 85 dB is potentially hazardous. Generally, the sound level and total period of exposure are two significant interrelate factors in evaluating the impact of sound in any situation (Azodo et al., 2018; Omubo-Pepple *et al.,* 2010).

Plant growth and development can be adversely affected by noise pollution. Photosynthetic process can be disrupted by high decibels leading to reduced plant production (Francis, *et al*., 2017). According to Barberousse *et al*. (2018), stress from induced noise can deter seed germination and thus affect plant production processes. Some species of plant also depend on definite acoustic signals for seed pollination, excessive noise can disrupt this process, leading to interruptions in ecological interactions and biodiversity (Pijanowski *et al*., 2011). A wide variety of animal species are adversely affected by noise pollution. Loud noises can disrupt natural habitats and behaviours of wildlife, causing altered migration patterns, changes in feeding and breeding habits, and increased stress levels (Shannon *et al*., 2016). Excessive noise can disrupt conveyance vital signals to animals that rely on acoustic communication for mating, territorial defense, or parental care (Brumm and Slabbekoorn, 2005).

According to Fahy (2001), Any method used to reduce the sound pressure in relation to a certain sound source and receptor is referred to as soundproofing. Increasing the distance between the source and the receiver, employing noise barriers to absorb sound waves, using dampening structures like sound mufflers, or using active anti-noise sound producers are some basic methods for minimizing sound pollution. The increase in dependency on electricity generators in Nigeria has led to spike in noise pollution both in homes and business places which has a damaging impact on the environment; human, animal and plant health. Effects of noise on humans include; irritation, interference with communication, distraction or loss of concentration, insomnia and high blood pressure. Noise-Induced Hearing Loss (NIHL), a progressive and seemingly undetectable decrease in hearing sensitivity, can be brought on by prolonged exposure to less powerful yet harmful sounds (Mbamali *et al.*, 2012; Olayinka, 2012). According to Mbamali *et al.* (2012), noise levels above the 70-75 dB recommended World Health Organization's (WHO) threshold can be linked to conditions such as hypertension, aberrant foetal development, intense emotions, and inappropriate behaviour. Such noise levels have also been reported to cause instantaneous hearing impairment as well as complaints and friction among neighbours. Excessive environmental noise may lead to heart-related issues. According to studies, high decibel sound has been linked to a sharp increase in blood pressure, since it narrows blood vessels and interferes with blood flow. The quantity of heartbeats per minute, or heart rate, likewise rises. These were demonstrated in a study where children living in noisy environments had heart rates that were higher than those of children living in less noisy environments (Bisong et al., 2004). The range of noise level of a normal electric generator is between 80-105 dB at 6.4 m. This noise level fall into very loud to uncomfortably loud level with respect to sensitivity of human ears. This makes electrical generators a source of noise pollution to the environment. In the United States, for instance, laws and regulations usually permit noise levels in residential homes to not exceed 67 dB, and in industrial locations not exceed 72 dB (Umar *et al.*, 2013). Most of the previous research on sound suppression for electric generators were focussed on the use of acoustic material to supress the noise of a selected generator (Amos *et al.*, 2018; Kakadiya *et al.*, 2007; Rajendra *et al.*, 2015; Umar *et al.*, 2013). According to Delany and Bazley (1970), acoustic quieting, noise mitigation and noise control can be used to limit unwanted noise. This study investigated the effect of noise reduction using three local materials (sand, foam and sawdust) on five different capacity of gasoline generators representing the range of petrol generator for both domestic and commercial uses in Nigeria.

## II. MATERIALS AND METHODS

### 3.1 Development of muffler cabinet

The muffler cabinet (Fig. 1 & 2) was designed and fabricated using a 2 mm mild steel and iron brazing to make it sturdy. The inner dimensions (length, width and breath) of the cabinet were 1 m × 1 m × 1 m. These dimensions were selected to be able to accommodate all the available petrol generators in use in Nigeria. The outer dimensions (length, width and breath) of the cabinet were 1.12 m × 1.12 m × 1.12 m, creating a hollow of 0.12 m for the acoustic materials. The cabinet was provided with door, air vent and suction fan.

Fig 1. The muffler cabinet

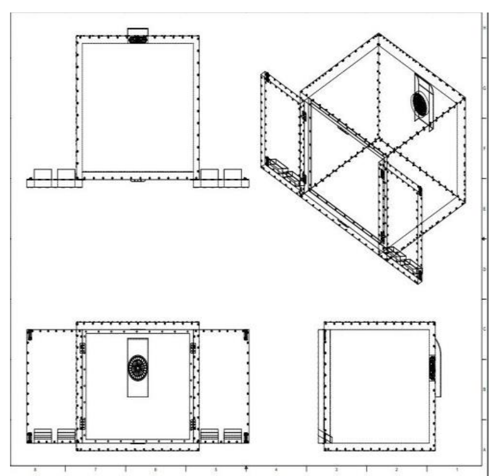

Fig 2. Schematic diagram of the muffler cabinet

### 3.2 Experimental procedure

The materials used for sound-dampening were sand, sawdust and foam. Mudashir (2022) assessed the acoustic quality of sawdust and sharp sand. Pajović *et al.* (2022) studied the properties of standard low density polyurethane lime foam. These materials were selected due to their locally availability and low cost. Five petrol generators of varying capacities 2, 3, 6, 10 and 14 kVA respectively were used for the experiment. The sound level from the generators were measured at varying distances of 0, 5, 10, 15 and 20 m respectively using a digital sound level meter UT353. The experiments were carried out in three replications with the generators outside and inside the muffler cabinet respectively. Two-way (ANOVA) was used to test the difference between generator sound inside and outside the cabinet at ($\alpha = 0.05$).

## IV. RESULTS AND DISCUSSION

The results of the experiments performed are presented in Figs. 2-5. The two-way Analysis of Variance (ANOVA) relationship at ($\alpha = 0.5$) between the noise levels from the generators outside the cabinet and generators placed inside the cabinet with different acoustic materials are presented in Table 1. As shown in Figs (2-5), the noise intensity decreased as distance from the generators increased. For the capacity of generators tested (2-14 kVA) at distances 0-20 m from the generators, the noise intensity ranged between 60.9-91.8 dB. The noise level produced by the 2 kVA generator outside the muffler cabinet at distances 0-20 m from the generator ranged from 60.9-83 dB. The noise level was reduced to 47-70.22 dB, 51.2-75 dB and 48.5-72.5 dB when the generator was placed in the muffler cabinet lagged with sawdust, sand and foam respectively as acoustic materials. This trend was the same for all the other generator capacities as shown in Figs (2-5). The muffler cabinet lagged with sawdust as acoustic material reduced the noise intensity to 47-80.1 dB. The muffler cabinet lagged with sand as acoustic material reduced the noise intensity to 52.1-78.7 dB. The muffler cabinet lagged with foam as acoustic material reduced the noise intensity to 48.5-73.8 dB. The noise ranges observed in this study were lower than 102.1 dB observed by Amos *et al.* 2018, observed from a 2.5 kVA placed in an open environment at a distance of 4.2 m from the generator, which was reduced by 15.5 dB when enclosed. The level of noise reduction observed in this study agrees with the findings of other researchers and Kuku *et al.* (2012) that sound proof enclosure reduce noise by as much as 20% from petrol generators. The adverse effect of noise on the environment is a function of noise level and length of exposure. 85 dB had been observed as a threshold beyond which sound becomes potentially dangerous (Robinson 1987; Dobie, 1993). All the three lagging materials used as acoustic materials for the noise muffler cabinet reduced the noise levels from the various generators below 85 dB.

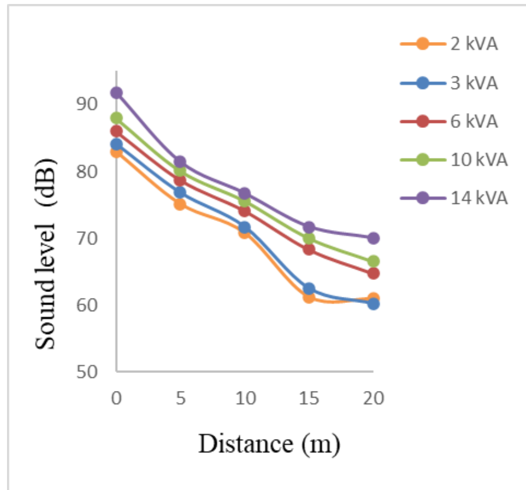


Fig 2. Noise level against Distance from Generators (Outside the Cabinet)

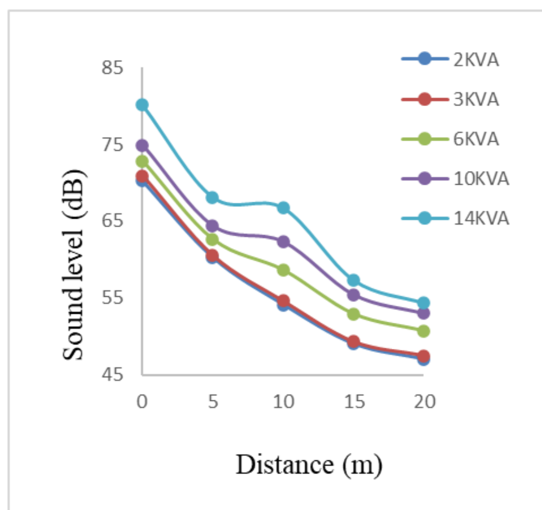


Fig 3. Noise level against Distance from Generators (Sawdust Cabinet)

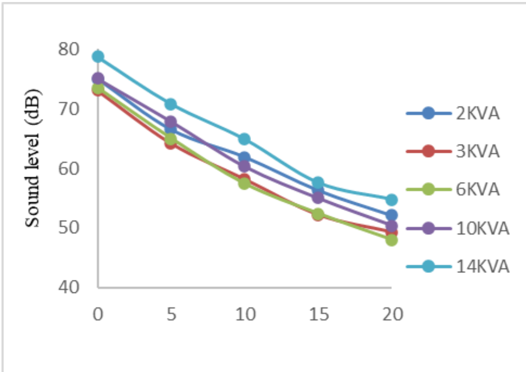


Fig 4. Noise level against Distance from Generators (Sand Cabinet)

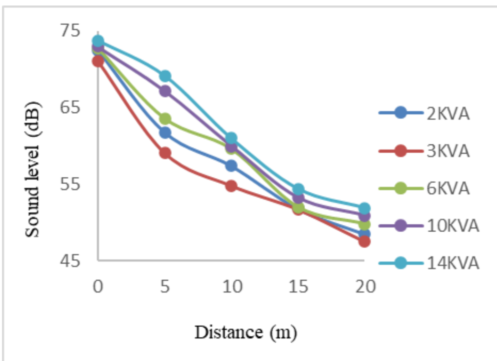


Fig 5. Noise level against Distance from Generators (Foam Cabinet)

The ANOVA relationship at (α = 0.5) between the noise levels from the generators outside the cabinet and generators placed inside the cabinet with different acoustic materials are presented in Table 1. The values of Probability of F lower than 0.05 indicates a significant difference in noise level between the outside in inside cabinet. As shown in Table 1, the probability values are $< 0.05$ for all the generators 2, 3, 6, 10 and 14 kVA respectively across all the distances investigated with different acoustic materials. Also, the very high of coefficient determination $R^2$ values $> 0.9990$ indicates a large significant effect of noise reduction from all the acoustic materials used for the experiment in comparison to generators outside the cabinet.

Table 1: ANOVA effect of material used and distance of measurement on sound loudness perceived

| Generator type | Source | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| | Distance (Dist) | 3160.461 | 4 | 790.115 | 6205.093 | 0.000 |
| | Material (Mat) | 89.054 | 2 | 44.527 | 349.688 | 0.000 |
| 2 kVA | Dist * Mat | 34.428 | 8 | 4.304 | 33.798 | 0.000 |
| | Error | 3.820 | 30 | 0.127 | | |
| | Total | 3287.763 | 44 | | | |
| | R Squared =0.999 | | | | | |
| | Distance (Dist) | 3060.735 | 4 | 765.184 | 2005.432 | 0.000 |
| | Material (Mat) | 63.342 | 2 | 31.671 | 83.005 | 0.000 |
| 3 kVA | Dist * Mat | 25.189 | 8 | 3.149 | 8.252 | 0.000 |
| | Error | 11.447 | 30 | 0.382 | | |
| | Total | 3160.712 | 44 | | | |
| | R Squared =0.9960 | | | | | |
| | Distance (Dist) | 3170.495 | 4 | 792.624 | 2588.394 | 0.000 |
| | Material (Mat) | .803 | 2 | 0.402 | 1.311 | 0.284 |
| 6 kVA | Dist * Mat | 29.741 | 8 | 3.718 | 12.140 | 0.000 |
| | Error | 9.187 | 30 | .306 | | |
| | R Squared =0.9960 | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 10 kVA | Distance (Dist) | 3032.152 | 4 | 758.038 | 539.285 | 0.000 |
| | Material (Mat) | 11.326 | 2 | 5.663 | 4.029 | 0.028 |
| | Dist * Mat | 44.336 | 8 | 5.542 | 3.943 | 0.003 |
| | Error | 42.169 | 30 | 1.406 | | |
| | Total | 3129.984 | 44 | | | |
| | R Squared =0.9870 | | | | | |
| 14 kVA | Distance (Dist) | 3402.789 | 4 | 850.697 | 577.494 | 0.000 |
| | Material (Mat) | 83.649 | 2 | 41.825 | 28.393 | 0.000 |
| | Dist * Mat | 55.851 | 8 | 6.981 | 4.739 | 0.001 |
| | Error | 44.193 | 30 | 1.473 | | |
| | Total | 3586.482 | 44 | | | |
| | R Squared =0.9880 | | | | | |

## CONCLUSION

A petrol generator muffler cabinet was produced. Sawdust, sand and foam were used as acoustic materials to lag the cabinet. Levels of noise from generators (2-14 kVA) when placed outside and inside the cabinet with three the different acoustic materials respectively were measured at various distances (0-20 m). The sound intensity from the generator when place outside ranged from 60.9-91.8 dB. The sawdust as acoustic material was most efficient as it reduced the noise intensity to 47-80.1 dB, followed by foam which reduced the noise intensity to 48.5-73.8 dB. Sand as acoustic material reduced the noise intensity to 52.1-78.7 dB. The noise intensity of all the generators generally decreased as distance from the generators increased. There was a significant difference between the noise level from the from generators when placed outside and inside the cabinet with the three different acoustic materials respectively. All three lagging materials used as acoustic materials for the noise muffler cabinet reduced the noise levels from the various generators below 85 dB which is the threshold beyond which sound becomes considered potentially dangerous.

## REFERENCES

[1] Amos, A. E, Olisa, Y. P., & Kotingo, K. (2018). Design and performance evaluation of a soundproof enclosure for a 2.5kVA Generator. J. Appl. Sci. Environ. Manage, 22(12): 1975-1978.

[2] Azodo, A. P. (2014). Electric power supply, main source and backing: A survey of residential utilization features. Int. J. Res. Stud. Manage. 3(2): 87-102.

[3] Azodo, A. P., Idama, O., Mezue, T. C., & Owoeye, F. T. (2018). Evaluation and analysis of environmental noise from petrol fuelled portable power generators used in commercial areas. Journal of Experimental Research, 6(1): 8-13.

[4] Babatunde, O. M., Adedoja, O. S., Babatunde, D. E., Denwigwe, I. H. (2019). Off-grid hybrid renewable energy system for rural healthcare centers: A case study in Nigeria. Energy Science and Engineering, 7(3), 676-693.

[5] Barberousse, A. (2018). Impact of road traffic noise on seed germination in urban orchids. Science of the Total Environment, 610–611, 268–276.

[6] Bisong, A. S., Umana, N. A., Onoyom-ita V., & Osim, E. E. (2004). Hearing acuity loss of operators of food grinding machines in Calabar, Nigeria. Nigerian Journal of Physiological Sciences, 19(1-2): 20-27.

[7] Brumm, H., & Slabbekoorn, H. (2005). Acoustic communication in noise. Advances in the Study of Behavior, 35, 151–209.

[8] Delany, M. E., Bazley, E. N. (1970). Acoustical Properties of Fibrous Absorbent Materials. J. Appli. Acous. 3: 105-116.

[9] Dobie, R.A. (1993). Medical-Legal Evaluation of Hearing Loss. New York, Van Nostrand Reinhold.

[10] Etukudor, C., Abdulkareem, A., & Ayo, O. (2015). The daunting challenges of the Nigerian electricity supply industry. Journal of Energy Technologies and Policy, 5(9): 25-32.

[11] Fahy, F. (2001). Foundations of Engineering Acoustics. Academic Press, London.

[12] Francis, C. D. (2017). Acoustic environments matter: Synergistic benefits to humans and ecological communities. Journal of Applied Ecology, 54(2): 376–379.

[13] Ibitoye, F. I., & Adenikinju, A. (2007). Future demand for electricity in Nigeria. Applied Energy, 84 (5): 492-504.

[14] Kakadiya, Y. K., Patel, B. S., & Hadiya, J. P. (2007). Design and Comparison of Mufflers Having Different Arrangements for Diesel Engine. SSRG International Journal of Mechanical Engineering (SSRG - IJME), 4(6): 24-31.

[15] Mbamali, I., Stanley, A. M., Zubairu, I. K. (2012). Environmental, health and social hazards of fossil fuel electricity generators: A users' assessment in Kaduna, Nigeria. American International Journal of Contemporary Research, 2(9): 2-8.

[16] Mudashir, G. (2022). Assessment of acoustic property of sawdust and fine sharp sand for the fabrication of sound-proof security door. Fudma Journal of Sciences, 6(1): 129 - 134.

[17] Nweke, J. N., Ekwue, A. O., Ejiogu, E. C. (2016), Optimal location of distributed generation on the Nigerian power system. Nigerian Journal of Technology, 35(2): 398-403.

[18] Okoro, R. C. (2014). Survey and analysis of noise by generating plants in some parts of the university of Calabar, Calabar, Cross River state Nigeria. Int. J. Res. Agric. Food Sci. 1;(3): 8-15.

[19] Olayinka, O. S. (2012). Noise pollution in urban areas: The neglected dimensions. Environmental Research Journal, 6(4):259-271.

[20] Omubo-Pepple, V. B., Briggs-Kamara, M. A., & Tamunobereton-ari I. (2010). Noise pollution in Port Harcourt metropolis: sources, effects and control. Pac. J. Sci. Technol. 11;(2): 592-600.

[21] Onwe, D. N., & Bamgboye, A. I. (2022). Engine Performance and Exhaust Emissions from Sandbox (Hura crepitans) Seed Methyl Ester. Journal of Engineering Research and Reports, 23(9): 1-12.

[22] Oseni, M.O. (2012). Households' access to electricity and energy consumption pattern in Nigeria. Renewable and Sustainable Energy Reviews, 16 (1): 990-995.

[23] Pajović, S., Bjelić, M., Grković, V., & Perić J. (2022). Acoustic properties of standard low density polyurethane lime foam. 27th Internation Conference, Noise and Vibration, University of Nis, Faculty of Occupational Safety, 137-142.

[24] Rajendra, K. K, Prakash, K. S., & Gopal S. (2015). A review on a noise reduction system in IC engine, Mechanical Engineering, Kirodimal Institute of Technology, Raigarh. International Journal of Engineering Sciences & Research & Technology (IJESRT), 2277-9655.

[25] Robinson, D. W. (1987). Noise Exposure and Hearing: A New Look at The Experimental Data. Health and Safety Executive Research report, 1/1987. H.M.S.O.

[26] Umar, H., Ahmad, A., Abid, A. K., & Taimur Q. (2013). Design and development of noise suppression system for domestic generators. European Scientific Journal, 4: 526-533.

[27] Willis, H. L, Scott, W. G. (2000). Distributed power generation: planning and evaluation: In Willis HL (ed.): Power Engineering. New York: Marcel Dekker, Inc.

[28] Yesufu, L. A., Ana, G., Umar, O. Z. (2013). Knowledge and perception of noise induced health hazards associated with generator use in selected commercial areas in Ibadan, Nigeria. Int. J. Collab. Res. Internal Med. Public Health Hazards, 5;(9): 581-595.