Assessment of Noise Pollution from Petrol Generators in Nigeria: An Analysis of Distance, Capacity and Age Variables

ABSTRACT

Irregular and epileptic power supply in Nigerian, Africa and some other parts of the globe has made electricity generators the primary source of power for domestic and commercial purposes in such places. These generators produce noise pollution to the environment. Noise pollution is hazardous to human hearing and health and it adversely affect plant growth and development.This study investigated the noise production from five different capacity gasoline generators of varying ages at varying distances, representing the range of petrol generator for both domestic and commercial uses in Nigeria. Five petrol generators of varying capacities 2, 3, 6, 10 and 14 kilo Volt Ampere (kVA), and age 1, 2, 3, 4, 5 years 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. Two-way Analysis of Variance (ANOVA) was used to test the difference between generators of different ages at the varying distances at (α = 0.05). The noise intensity decreased as distance from the generators increased. The lowest noise was recorded for the generators at age 1, and increased as the age of the generators increased. For the capacity of generators tested, the noise level produced by 1 year old generators at distances 0-20 m from the generator ranged from 60.9-83 dB for 2 kVA generator; 60.2-84.1 dB for 3 kVA generator; 64.7-86 dB for 6 kVA generator; 66.52-88.02 dB for 10 kVA generator; 70-91.8 dB for 14 kVA generator respectively. The study showed that noise level from generators increased as they age. The noise ranges from all the generators indicates noise pollution as they are averagely above the World Health Organization specified noise limits of 30 and 70 decibels for both indoor and outdoor cases respectively.Consequently, noise generated from variety of petrol generators is a source of noise pollution.

Keywords: Electricity; electric generators; petrol generators; noise; noise pollution

1. INTRODUCTION

1.1 Background

Mechanical power required in supplying most of global energy needed for global industrialization and motorization is supplied by fossil fuels [1]. 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 [2]. 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 othersources of energy such as niobium and nuclear [3; 4]. According toBabatunde *et al*[5], only 45% of Nigerians have access to electricity supply. This access is both unstable and unreliabledue to inadequate generation and incessant collapse of grid [6]. 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 [7] 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.

1.2 Noise Pollution

Sound, according to Amos*et al* [12] is a productan objectvibratingin open airand emittingpressure waves into the air. Thedecibel (dB) scale defines the level of sound from 80 to 100 dB as (very loud), 100 to 125 dB(uncomfortable) and 140 dB (threshold ofpain).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 [8]. 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 [9; 10; 24]. According Okoro[11], there has been a steady increase in the rate of importation of electric power generator over the years. Babatunde *et al*[5] estimated the importation of about 60 million generators of varying sizes in Nigeria, used massively in offices, business premises, homes, schools, churches and others. The intense cases are shopping or commercial centers, where several units are operating simultaneously to run businesses. Unmuffled gasoline and diesel engines produces exhaust noise in the range of 85-100 and 100-125 decibel (dB) respectively.The human ear has the ability to tolerate noise from 0-140 dB. Noise from 0-80 dB can be considered healthy. 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. Prolonged exposure to high decibel levels can lead to hearing damage[11; 13].

1.3 Effects of Noise Pollution

Plant growth and development can be adversely affected by noise pollution. Photosynthetic process can be disrupted by high decibels leading to reduced plant production [14]. According toBarberousse [6], 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. 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. Excessive noise can disrupt conveyance vital signals to animals that rely on acoustic communication for mating, territorial defense, or parental care [16]. According to Brumm and Slabbekoorn[16], 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 tocause instantaneous hearing impairment as well as complaints and friction among neighbours. Excessiveenvironmental 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 heart beats 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[17].

The increase in dependency on electricitygenerators 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 bloodpressure. 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 [18; 19]. 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 tosensitivity of human ears. This makes electrical generators a source of noise pollutionto 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 [20].Noise pollution from generators has been mostly mitigated using mechanical silencers for active noise control, and acoustic foam or textile materials for passive control methods [21].

Most previous research on noise pollution from petrol generators focused on questionnaire responses from users and assessments of noise pollution from clustered generators [22; 23; 24]. This study aims to provide a more detailed analysis by investigating noise pollution at varying distances from five gasoline generators of different capacities and ages, representing both domestic and commercial uses in Nigeria.

2. MATERIALS AND METHODS

2.1 Experimental procedure

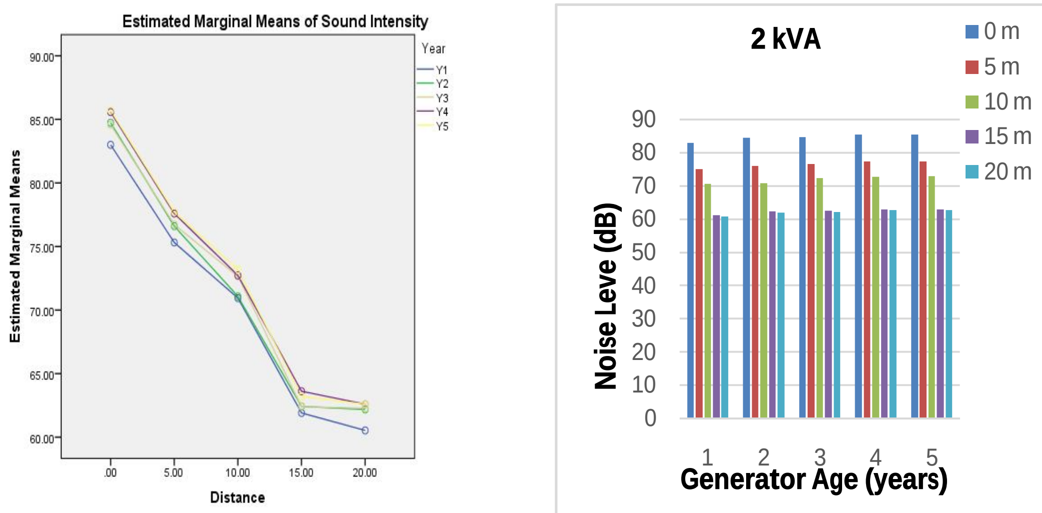
The experiment was carried out at the Department of Agricultural and Food Engineering, Faculty of Engineering, University of Uyo, Nigeria, lying between latitude $4^{0}32^{I}$ and $5^{0}33^{I}$ N and longitude $7^{0}25^{I}$ and $8^{0}25^{I}$ E. Five petrol generators of varying capacities 2, 3, 6, 10 and 14 kilo Volt Ampere (kVA), and age 1, 2, 3, 4, 5 years respectively were used for the experiment. A digital sound level meter with model no. UT353 mini sound meter[range (30-130 dB); 0.1 dB resolution; ±1.5 accuracy; response rate (31.5-8 Hz)] was used to measure the ambient sound level. Thereafter, the sounds levels from the generators were measured at varying distances of 0, 5, 10, 15 and 20 m respectively. The experiments were carried out in three replications. The mean differences of the experimental results were analyzed using Two-way Analysis of Variance (ANOVA) to test the difference between generators of different ages at the varying distances at ($\alpha = 0.05$).

2.2 Sound Producing Machines and Measuring Techniques

Reports of noise as occupational hazard in many workplaces, is common in the iron and steel industry,foundries, sawmills, textile mills, airports, and aircraft maintenance shops, crushing mills, and more [25]. These adverse developments have brought about the need for noise suppression solutions. These include studies on occupational sound levels from some noise sources with respective reference values reported[26]. For instance, mechanical noises from machine parts such as turbines can be listed as accruing from auxiliary equipment such as gearbox, generators, drift drivers, cooling fans, hydraulics [27]. Some machine parts considered as auxiliary equipment constitute considerable amount of noise source which steps are to be taken to minimize to the barest minimum [28].Evaluation of the effects of noise pollution on the environment for effective control can be achieved by arranging noise maps [29]. According to Caliskan *et al.*[30], noise maps, either regional or local are ideal to be prepared at certain times of the day. Noise map should be made for the stage, tent, generators and other structures that are planned to be used temporarily on the facility or an area [31]. Noise Mapping Guide, [32], studied noise map for generators. Hermes, [33] evaluated the noise generated from commercial and industrial generators, commercial workplaces and industrial production areas. They noted that the parameters such as the source and the path of sound and the receiver should be evaluated distinctly. They observed that the most important factor in reducing noise pollution is to control it at source. Thus, the environment can be protected from the noise generated at the source. Furthermore, noise can be reduced in the area where it spreads. However, noise reduction at the source is more effective. Noise was reduced in different generator types using with different materials with acoustic properties[34].

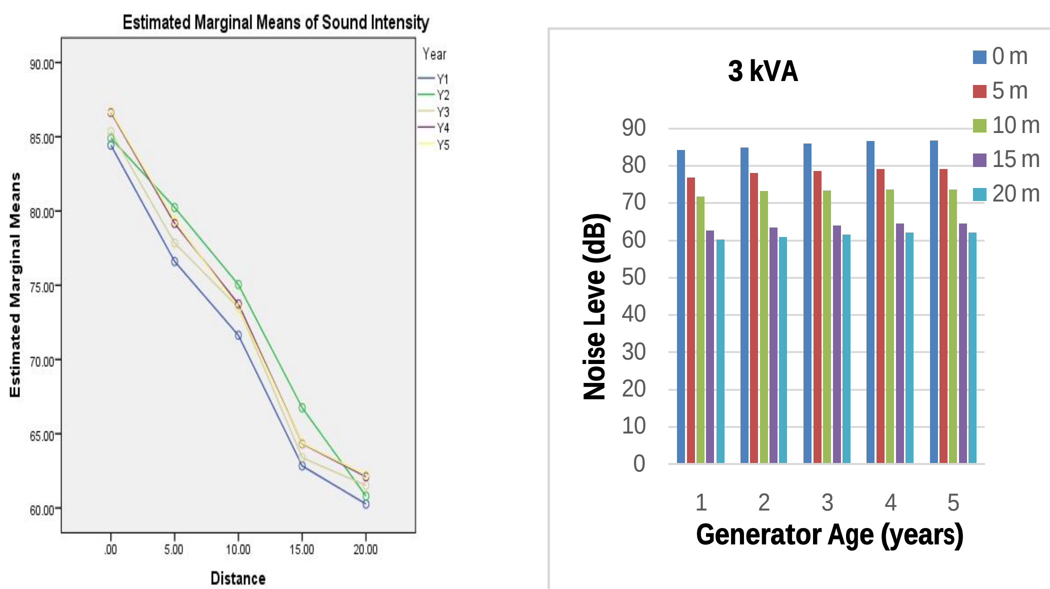
3. RESULTS AND DISCUSSION

The results of the estimated marginal mean of sound intensity generated from the various generators at varying distances and years are presented in Figs 1-5. The model relationship of sound loudness from generator capacities against age and distance is as shown in Table 1. The two-way (ANOVA) relationship at (α = 0.5) between the ages of generators and distances from the generator and sound level is shown in Table 2.



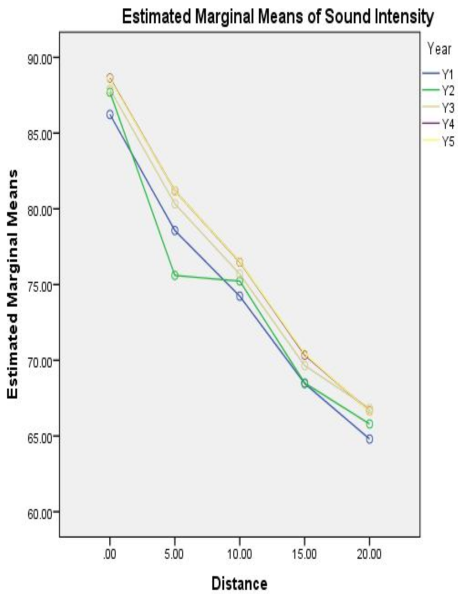
(a) **(b)**

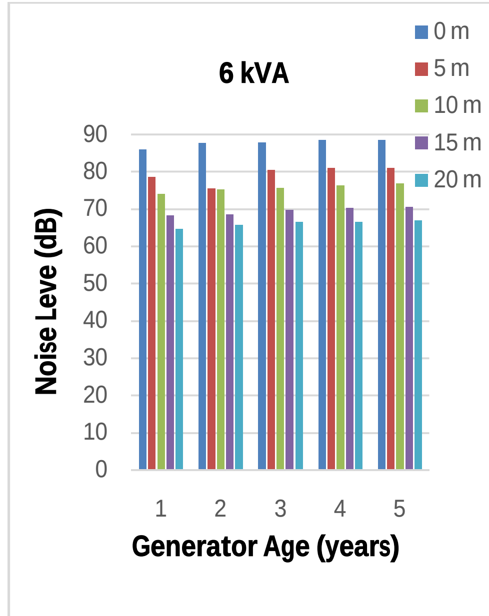
Fig. 1(a; b). Estimated marginal mean of sound intensity generated from 2 kVA generator set at different distances and years



(a) **(b)**

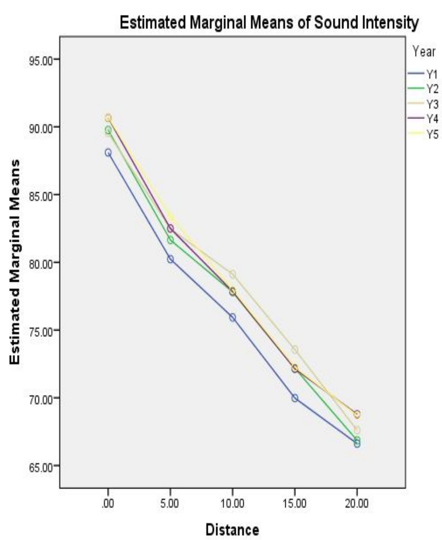
Fig. 2 (a; b). Estimated marginal mean of sound intensity generated from 3 kVA generator set at different distances and years

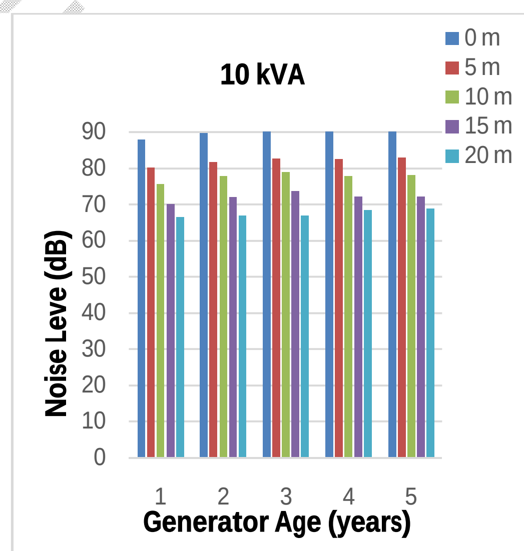




(a) **(b)**

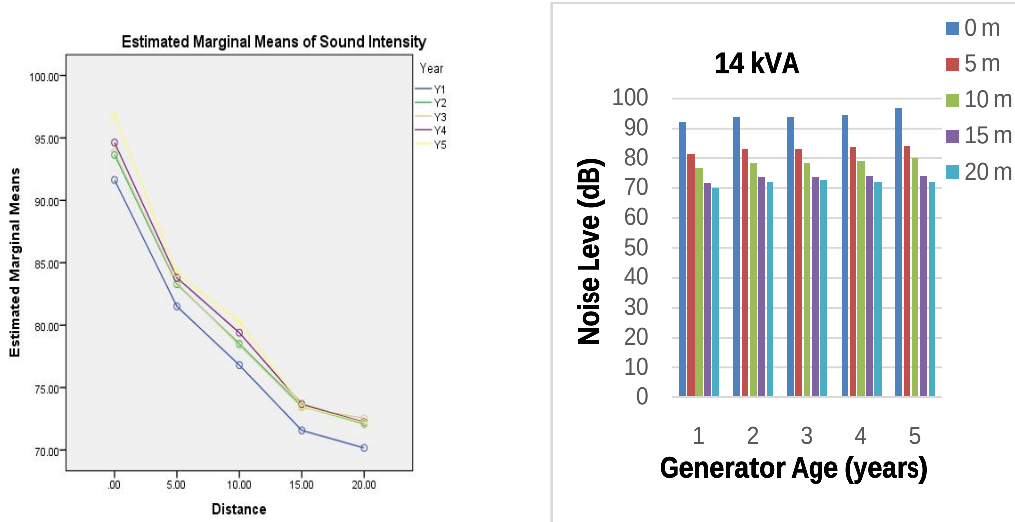
Fig. 3 (a; b). Estimated marginal mean of sound intensity generated from 6 kVA generator set at different distances and years





(a) **(b)**

Fig. 4 (a; b). Estimated marginal mean of sound intensity generated from 10 kVA generator set at different distances and years



(a) (b)

Fig. 5. Estimated marginal mean of sound intensity generated from 14 kVA generator set at different distances and years.

As shown in Figs (1-5), the noise intensity decreased as distance from the generators increased. The lowest noise was recorded for the generators at age 1, and increased as the age of the generators increased. For the capacity of generators tested, the noise level produced by 1 year old generators at distances 0-20 m from the generator ranged from 60.9-83 dB for 2 kVA generator; 60.2-84.1 dB for 3 kVA generator; 64.7-86 dB for 6 kVA generator; 66.52-88.02 dB for 10 kVA generator; 70-91.8 dB for 14 kVA generator respectively. This trend was the same for all the other generator capacities for 2-5 years. The results are within the range of 85.33 ± 1.47 dB at 3 m distance obtained by [35]. Similarly, [22], obtained mean values of 109.86, 85.95, 83.09, 80.68 and 81.69 decibels at 1-3 m distances from generators capacities of 0.5-5.0 kVA. The noise levels observed in this study are above the World Health Organization specified noise limits of 30 and 70 decibels for both indoor and outdoor cases respectively. Exposure to excessive or repetitive noise over a long duration of time can result in loss of hearing. According to [36], exposure to sound level above the range of 70 to 75 decibels can cause high blood pressure, abnormal fetal changes, extreme emotions and behaviour. Study by [37], indicated that the degree of the effect of vibration on man and animal depends the intensity and extent of exposures. It was observed that the sound levels from the generator increases as the age of the generator increases as shown in Table 1.

Table 1. Model relationship of sound loudness from generator capacities against age and distance

Capacity of generator (kVA)	Sound Loudness (decibel)			
	Age of Generator (year)		Distance (m)	
2	1	70.34 ± 8.70	0	84.72 ± 1.01
	2	71.40 ± 8.91	5	76.79 ± 0.92
	3	71.73 ± 8.87	10	72.12 ± 0.98
	4	72.42 ± 8.96	15	62.71 ± 0.73
	5	72.48 ± 9.10	20	62.03 ± 0.82
	1	71.15 ± 9.20	0	85.61 ± 1.00

3	2	73.54 ± 9.50	5	78.64 ± 2.00
	3	72.32 ± 9.30	10	73.48 ± 1.55
	4	73.19 ± 9.47	15	64.33 ± 2.57
	5	73.23 ± 9.48	20	61.38 ± 0.80
6	1	74.46 ± 7.81	0	87.80 ± 0.90
	2	74.57 ± 7.85	5	79.38 ± 2.19
	3	76.07 ± 7.82	10	75.63 ± 0.89
	4	76.66 ± 8.07	15	69.48 ± 0.89
	5	76.66 ± 8.05	20	66.13 ± 0.79
10	1	76.18 ± 7.87	0	89.76 ± 0.99
	2	77.65 ± 8.14	5	82.05 ± 1.11
	3	78.46 ± 7.77	10	77.74 ± 1.07
	4	78.38 ± 8.01	15	72.02 ± 1.02
	5	78.60 ± 8.12	20	67.71 ± 0.97
14	1	78.33 ± 8.04	0	94.11 ± 1.72
	2	80.21 ± 8.07	5	83.22 ± 0.96
	3	80.31 ± 8.09	10	78.67 ± 1.20
	4	80.74 ± 8.37	15	73.14 ± 0.85
	5	80.19 ± 8.20	20	71.82 ± 0.89

Table 2. ANOVA effect of age of generator and distance from generator on sound loudness

Generator Capacity (kVA)	Source	Sum of Squares	df	Mean Square	F	Sig.
2	D	5546.983	4	1386.746	16720.404	0.000
	Y	46.020	4	11.505	138.720	0.000
	D * Y	6.486	16	0.405	4.887	0.000
	Error	4.147	50	0.083		
	Total	5603.636	74			
	R Squared =0.999					
3	D	6009.094	4	1502.274	645.479	0.000
	Y	56.663	4	14.166	6.087	0.000
	D * Y	33.538	16	2.096	0.901	0.573
	Error	116.369	50	2.327		
	Total	6215.663	74			
	R Squared =0.981					
6	D	4353.927	4	1088.482	44631.855	0.000
	Y	72.131	4	18.033	739.412	0.000
	D * Y	36.698	16	2.294	94.047	0.000
	Error	1.219	50	0.024		
	Total	4463.975	74			
	R Squared =1.000					
10	D	4442.118	4	1110.529	24367.252	0.000
	Y	61.175	4	15.294	335.578	0.000
	D * Y	16.758	16	1.047	22.981	0.000
	Error	2.279	50	0.046		
	Total	4522.329	74			
	R Squared =0.999					
	D	4876.314	4	1219.078	29307.587	0.000
	Y	77.591	4	19.398	466.338	0.000
	D * Y	16.482	16	1.030	24.766	0.000

14	Error	2.080	50	0.042
	Total	4972.467	74	
	R Squared =1.000			

Note: D = Day, Y = Year

The values of Probability of F lower than 0.05 as shown in Table 2 indicates a significant difference in noise level of the generators as they age. The probability values are less than 0.05 for all the generators 2, 3, 6, 10 and 14 kVA at age 1, 2, 3, 4 and 5 years respectively across all the distances investigated. Also, the very high of coefficient determination R^2 values are greater 0.9990 indicates a large significant effect.The sound intensity was lowest between year 1-2 and loudest between year 4-5.

4. CONCLUSION

Investigation of noise pollution from different petrol generators of varying capacities and age was carried out. The sound levels five petrol generators of varying capacities (2-14 kVA) at age (1-5 years) at distances (0-20 m) were measured. The noise levels produced by the generators were lowest at year one and increased as the number of years increased. The noise level decreased as distance away from the generators increased. The mean noise from the range of (60.9-96.68 dB) observed in this study are above the World Health Organization specified noise limits of 30 and 70 decibels for both indoor and outdoor cases respectively.Noise generated from variety of petrol generators is a source of noise pollution, thus, there is need for solutions for noise reduction from these generators.

REFERENCES

1. Onwe D N, BamgboyeAI. Engine Performance and Exhaust Emissions from Sandbox (Hura crepitans) Seed Methyl Ester. Journal of Engineering Research and Reports. 2022;23(9):1-12.
2. Etukudor C, Abdulkareem A, Ayo O. The daunting challenges of the Nigerian electricity supplyindustry. Journal of Energy Technologies and Policy. 2015;5(9):25-32.
3. Ibitoye FI, Adenikinju A. Future demand for electricity in Nigeria, Applied Energy. 2007;84(5):492-504.
4. Oseni MO. Households' access to electricity and energy consumption pattern in Nigeria. Renewable and Sustainable Energy Reviews. 2012;16(1):990-995.
5. Babatunde OM, Ayegbusi CO, Babatunde DE, Oluseyi PO, Somefun TE. Electricity supply in Nigeria: Cost comparison between grid power tariff and fossil-powered generator, International Journal of Energy Economics and Policy, 2020;10(2):160-164.
6. Nweke JN, Ekwue AO, Ejiogu EC. Optimal location of distributed generation on the Nigerian power system. Nigerian Journal of Technology. 2016;35(2):398-403.
7. Kakadiya YK, Patel BS, Hadiya JP. Design and Comparison of Mufflers Having Different Arrangements for Diesel Engine. SSRG International Journal of Mechanical Engineering (SSRG - IJME). 2007;4(6):24-31.
8. Willis HL, Scott WG. Distributed power generation: planning and evaluation: In Willis HL (ed.): Power Engineering. New York: Marcel Dekker, Inc. 2000.
9. Ibitoye FI, Adenikinju A. Future demand for electricity in Nigeria, Applied Energy. 2007;84(5):492-504.
10. Yesufu L.A, Ana G, Umar OZ. 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. 2013;5(9):581-595.

11. Okoro RC. 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. 2014;1(3):8-15.
12. Amos AE, Olisa YP, Kotingo K. Design and performance evaluation of a soundproof enclosure for a 2.5kVAGenerator. J. Appl. Sci. Environ. Manage. 2018;22(12):1975-1978.
13. Rajendra KK, Prakash KS, Gopal S. 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). 2015;2277-9655.
14. Francis CD. Acoustic environments matter: Synergistic benefits to humans and ecological communities. Journal of Applied Ecology. 2017;54(2):376-379.
15. Barberousse A. Impact of road traffic noise on seed germination in urban orchids. Science of the Total Environment. 2018;610-611:268-276.
16. Brumm H, SlabbekoornH. Acoustic communication in noise. Advances in the Study of Behavior. 2005;35:151-209.
17. Bisong AS, Umana NA, Onoyom-ita V,Osim EE. Hearing acuity loss of operatorsof food grinding machines in Calabar,Nigeria. Nigerian Journal of PhysiologicalSciences. 2005;19(1-2):20-27.
18. Mbamali I, Stanley AM, Zubairu IK.Environmental, health and social hazardsof fossil fuel electricity generators: Ausers' assessment in Kaduna, Nigeria.American International Journal ofContemporary Research. 2012;2(9):2-8.
19. Olayinka OS. Noise pollution in urbanareas: The neglected dimensions.Environmental Research Journal. 2012;6(4):259-271.
20. Umar H, Ahmad A, Abid AK, Taimur Q. Design and development of noise suppressionsystem for domestic generators. European Scientific Journal. 2013; 4:526-533.
21. Buluklu HM, Koçyiğit FB, Köse E. Analysis of different methods of suppressing generator noise reaching indoor noise European Mechanical Science. 2022; 6(3):161-178.
22. Azodo AP, Idama O, Mezue TC, Owoeye FT. Evaluation and analysis of environmental noise from petrol fuelled portable power generators used in commercial areas. Journal of Experimental Research. 2018;6(1):8-13.
23. Onwuka SU, Ezigbo CM, EnechePSU. Assessment of noise pollution from powergenerating sets: a case study of Nnewi-North L.G.A., Nigeria. Journal of Scientific Research & Reports. 2017;16(3): 1-12.
24. Azodo AP,AdejuyigbeSB. Examination of noise pollution fromgenerators on the residents of Obantoko,Ogun State, Nigeria. Asian Journal of Engineering, Sciences & Technology. 2013;3(1): 31-41
25. Gerges S, SehrndtGA. 5 Noise Sources. OccupationalExposure to Noise: Evaluation,Prevention andControl. Federal University of Santa Catarina, MechanicalEngineering Department, Noise and Vibration Laboratory. (2001)
26. BergerEH, NeitzelR, KladdenCA. Noise navigatorTM sound level database with over 1700 measurementvalues EAR 88-34/HP 3M Personal Safety DivisionE-A-RCAL Laboratory, Univ. of Michigan, Dept. of EnvironmentalHealth Science, Ann Arbor, (2015) MI June 26, Version1.8. E.T: 20.12.2021.

27. Fıcıcı F, Dursun B, Gokcol C. Investigation of NoiseOriginating from Wind Energy Systems, SAU. Journal ofScience. (2007);2(1):54-62.
28. VictoriaE. Noise from Industry in Regional VictoriaRecommended Maximum Noise Levelsfrom Commerce,Industry and Trade Premises in Regional Victoria. Publication1411. (2011) Authorised and published byEPA Victoria, 200 Victoria Street, Carlton. E.T: 05.07.
29. WabarakatuhAW, SejahteraS. Guidelines forEnvironment Noise Limits and Control, hereby Publishedby the Department of Environment is a new publicationto supersede the previously published Planning Guidelinesfor Environmental Noise Limits and Control. (2007).
30. Calışkan M, Bakırcı E. Mapping the EnvironmentalNoise Emitted from the Highway and Determining ItsEffect on the Exterior of Buildings, 9th National AcousticsCongress, METU Culture and Congress Center, Ankara. (2011).
31. Technical assistance project for the capacity to implementthe environmental noise Directive Europe Aid/131352/D/SER/TR Technical Assistance Project for the Capacity toImplement the Environmental Noise Directive, (2015). TurkeyAnnex A:Catalog of Possible Noise Reduction Measures,Output 8.1, APPENDIX A: Possible noise reductionmeasures Catalog 28 August 2015. E.T: 24.07.2021
32. Noise Mapping Guide. Harmonization and Implementationof EU Directives on Environmental NoiseAssessment and Management European Union TwinningProject. TR/2004/IB/EN/ 02 Noise Mapping Guide. (2008)
33. HermesM. Understanding commercial and industrialgenerator noise, Generac Power Systems,1-3, E.T:08.07. (2021).
34. Toprak R, Akturk N. Raylı ulaşım sistemlerininneden olduğu gurultu ve cevresel etkileri. Turkiye MuhendislikHaberleri. (2002):417, 33.
35. Jibiri NN, Olaluwoye MO, Ayinmode BO. Assessment of health effects of noise and vibration levels at major business complexes and markets in Ibadan metropolis. Nig. J. Health Sci. 2015;5(4):69-75.
36. Osuntogun BA, Koku CA. Environmental impacts of urban road transportation in South-Western states of Nigeria. J.Appl. Sci. 2007;7(16):23-58.
37. Segerink FB, Korterik JP, OfferhausHL. Vibration transfers to measure the performance of vibration isolated platforms on site using background noise excitation. Rev. Sci. Instrum. 2011;82(6):065-111.