MODELING THE RELATION BETWEEN NOISE LEVELS AND DISTANCE FROM A 500 kVA POWER GENERATOR

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ABSTRACT

Noise from sources like power generators degrades the quality of our environment. It is known to produce many adverse effects both on humans and on structures. Some existing models do not consider the distance of measurement in evaluating noise pollution, such does not make the results to be of high precision. This work therefore evaluates the relation between l noise pollution and distance from a 500 kVA power generator. Hence, measurements of noise levels with respect to distance, x from the power generator were considered. Environmental noise models were developed by using the relevant displayed parameters. The parameters include the maximum noise level of the power generator, the attenuation coefficient and the coefficient of determination. Then, the results obtained from the models developed in this work, $L_{(modelled)}$ were compared with the results obtained from the physical measurements, $L_{(measured)}$. The results revealed that the maximum noise level of a 500 kVA power generator (i.e. at source or x = 0 m) was 97.44±0.37 dBA. The corresponding distances, x_c in meters at which its adverse effects covered in the residential areas was $0 \leq x_c \leq 87$. Also, the corresponding distances, x_s in meters in which it can be sited from the residential areas was $88 \leq x_s \leq \infty$. The results revealed that the equivalent continuous noise level, L_{eq} decreased as x increased. It was shown that there was no significant difference between $L_{(measured)}$ and $L_{(modelled)}$. Therefore, with the consideration of distance *(x)*, the models developed in this work are recommended to be used as more reliable tools for environmental noise impact assessments.

INTRODUCTION

Environmental noise is described by World Health Organization (WHO) as community noise or residential noise or domestic noise (WHO, 1999). The most important sources of community noise are air, rail and road traffic, neighbourhood, municipal work, and the construction plant, among others. Usually, noise from neighbourhood originates from building and installations associated with the food preparation business like cafeterias, restaurant, and discotheques; from recorded or live music; from playgrounds and car parks; from sporting events including motor sports; and from household animals for example barking dogs. The major sources of indoor noises include aeration systems, home appliances; office machines, and neighbours etc. (Ekott, 2018).

In the United States of America, the Environmental Protection Agency (EPA) identified noise as a hindrance since in the 1970s (Menkiti and Ekott, 2014a). Then, the agency carried out a main study of noise and has continued to bring up to date its results. This means that the study of noise is a continuous phenomenon. As with all pollutants, noise degrade the value of our environment and is known to produce various negative effects both on structures and on humans. Noise has escalated to the point where it is currently the most important peril to the superiority of our existence. This increase in noise can be attributed to the ever increasing number of people in the globe and the growing levels of economic affluence (Menkiti, 2001a).

In this context, noise is defined as unpleasant sound (Schmidt, 2005). However, noise can be described as the unwanted sound in the unwanted location at the unwanted occasion. The degree of "unwantedness" is usually a psychological issue since the effects of noise can range from temperate irritation to everlasting hearing loss, and may be rated in a different way by special observers (Ekott, 2018). For this reason, it is often exigent to establish the benefits of dropping a specific noise. Noise does affect the inhabitants, humans, fauna, etc, in the natural environment. Some definite places influence noise contacts; so it is invasive that it became difficult to run away from it. The public opinion polls almost constantly rank noise in the list of the most bothersome residential irritations. The industrial noise is one of the most annoying sources of noise complaints (Ekott, 2011). Community noise intrusions like traffic noise can obstruct speech communication, interfere with sleep and relaxation and disturb the capacity to perform difficult tasks (Kiely, 1998).

In 1993, a study carried out by Cornell University indicated that children exposed to noise during classes experienced problem with various cognitive developmental delays in addition to words discrimination. Specifically, the writing learning mutilation called dysgraphic is usually related to stress on environment during classes (Clark, Head and Stansfeld, 2013 and Stansfeld *et al*., 2005) Noise has been connected to vital cardiovascular health risks. In 1999, the WHO drew a conclusion that the existing evidence shown predicted a weak relationship between hypertension and long term exposure to noise beyond 67 – 70 dBA (Ising, *et al*., 1999). More current studies have recommended that noise levels of 50 dB(A) at night may also increase the risks of myocardial infarction by constantly enhancing production of cortisol (Essiett *et al*., 2010). The British Columbia Work's Compensation Board (WCB) has set 85 dB as its highest tolerant level in the work place. Above this limit hearing protection should be used. It states that the threshold of pain is attained at 120 dB and it classifies 140 dB as excessive hazard level. WHO safety noise levels are similar while EPA of Nigeria tends to have even a stricter standard of 70 dB as a maximum safe level of noise in work place. They gave the safe level around home to be 50 – 55 dB (Ekott and Menkiti, 2015).

Researchers have shown that constant noise above 55 dBA causes serious annoyance and above 50 dBA moderate annoyance at home (WHO, 2007). In a non-work place and for health and safety purposes, 55 dBA is set as a safety noise level for outside and 45 dBA inside. Hospital and school permissible levels of noise are 35 dBA (WHO, 1999). In Britain, the current and advanced Ministry of Agriculture regulations established in January 2002 state that propane cannons can be no closer than 150 meters from residential areas, and 100 meters from other kinds of noise makers. These machines generate noise at levels between 115 and 130 dB. At 100 meters the noise generated is above 80 dB, and greater than 75 dB at 150 meters, which is much greater than specified safe levels for around the residence. In fact, beyond 80 dB is near to the level at which ear protection should be used (Menkiti and Ekott, 2014a). Noise beyond harmless levels leads to numerous health impacts which include high blood pressure, annoyance, sleep loss, stress, hearing impairment, loss of productivity and the ability to concentrate, among others.

Hence, the study of noise is highly imperative so as to create awareness on the impacts of noise on the environment for the betterment of our society. In this research, the evaluation of environmental noise levels as they vary with distances and the development of models for predicting and controlling environmental noise pollution from a 500 kVA power generator shall be carried out.

MATERIALS AND METHODS

Physical Measurements

All the noise measurements were made using the sound level meter (SLM), model WensnWS1361 with ½ inch Electret condenser microphone. This model has a weighting with a measuring range 30 to 130 dBA, weighting with measuring range 35 to 130 dBC and 0.1dB resolution with fast/slow response. It is equipped with a built in calibration check (94.0 dB) and tripod moving. It has an accuracy of ± 1.5 dB. It has AC and DC outputs for frequency analyzer level recorder, Fast Fourier Transform (FFT) analyzer, graphic recorder and others. It also has electronic circuit and readout display and a weight of 308 g. The microphone senses the small air pressure variations related to sound and converts them into electrical forms. These signals are then passed to the electronic circuitry of the instrument for processing. The readout displays the processed sound levels in dB. The sound level meter picks the sound pressure level at one instance in a certain location. Measurements were taken by adjusting the sound level meter to A-weighting network in all the sampling locations. The sound level meter was calibrated by the manufacturer. During the noise level measurements, the microphone of the sound level meter was positioned at a distance of above 1 m from the main source at a height of 1.2 m above the ground and windshield was always used for accuracy. Work place noise level measurements were taken on slow response. Here, the response rate is the time period over which the instrument averages the sound level before displaying it on the readout. Fast response was used for fast varying noise. Measurement of workplace sound pressure was made in an uninterrupted noise field in the workplace, with the microphone located at the position normally occupied by the ear exposed to the highest value of exposure (EC, 1986).

Measurement of Noise Levels with Distance

In this case, a factory with a 500 kVA power generator was identified and measurements of noise levels from it as they vary with distance were taken. All noise level measurements were carried out using the sound level meter stated above, while distance measurements were made using a measuring tape. Lastly, the equivalent continuous noise levels (L_{eqs}) for them were evaluated.

Calculating the Equivalent Continuous Noise Level (L_{Aeq})

The L_{Aeq} is the steady noise level over a certain period of time that generates very similar quantity of A-weighted energy as the varying level over identical period. It is presented in equation (1) and it is measured in dBA.

$$L_{Aeq} = 10\log_{10}\left(\frac{1}{T}\int_0^T 10^{0.1L_i}\,dt\right) \qquad 1$$

where, T = time period over which L_{Aeq} is determined

L_i = noise level in the ith sample

Formula used for calculating the equivalent continuous noise level L_{eq} of a noise source, *N* at a particular distance, x is presented in equation (2) (Kiely, 1998).

$$L_{eq} = 10\log_{10}\{\frac{1}{T}\{10^{0.1L_N}\Delta T_N + 10^{0.1L_B}\Delta T_B\}\} \qquad 2$$

The noise level of a noise source, L_N is presented in equation (3) (Cunniff, 1977; Kiely, 1998).

$$L_N = 10\log_{10}(10^{0.1L_{TOTAL}} - 10^{0.1L_B}) \qquad 3$$

where, T =Time period over which L_{eq} is determined

ΔT_N =Time period over which noise level of a noise source is measured

ΔT_B =Time period over which background noise level is measured

L_N =Noise level of a noise source in dBA

L_B =Background noise level in dBA

L_{TOTAL} =Total noise level in dBA. and,

T = 5 minutes, ΔT_N = 2 minutes, ΔT_B = 3 minutes

Noise Modeling

The data obtained were analyzed and the linear regression method was applied. Hence, linear fitting models were developed for it by using the relevant displayed parameters. Finally, a general model for evaluating, controlling and predicting environmental noise pollution from a source of this type was developed.

RESULTS AND DISCUSSION

Relation between noise levels and distance from a 500 kVA power generator

The results (Fig. 1) show that when the 500 kVA power generator is switch off, the environment is conducive as the background noise level at any distance, *x* is less than the WHO safety noise level of 55 dBA for a non-work place. In terms of the L_{eq}, the power generator affects the residents up to a distance of about 75 meters. At this distance (75 meters), the approximate L_{eq} value is 57.03 dBA instead of the WHO level of 55 dBA. It is observed that the noise level with generator and the noise level of the generator alone are approximately the same up to a distance of about 85 meters. This implies that the total noise level and the generator noise level have approximately the same frequency up to the distance of about 85 meters. Also, it should be noted here that the generator noise can be heard beyond a distance of 100 meters. This is due to the fact that, at 100 meters from the power generator (the noise source) the generator noise level is greater than the background noise level by 6.8 dBA. Hence, by physical measurements such a 500 kVA power generator should be installed beyond a distance of 85 metres from residential areas.

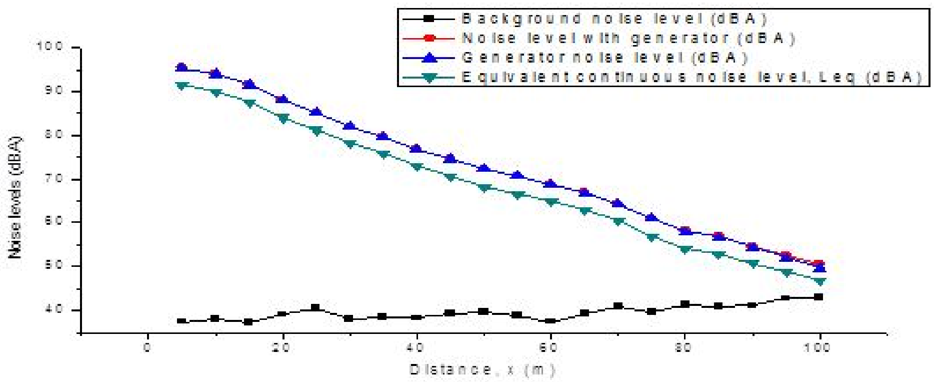

Figure. 1: A 500 kVA power generator noise levels against distance

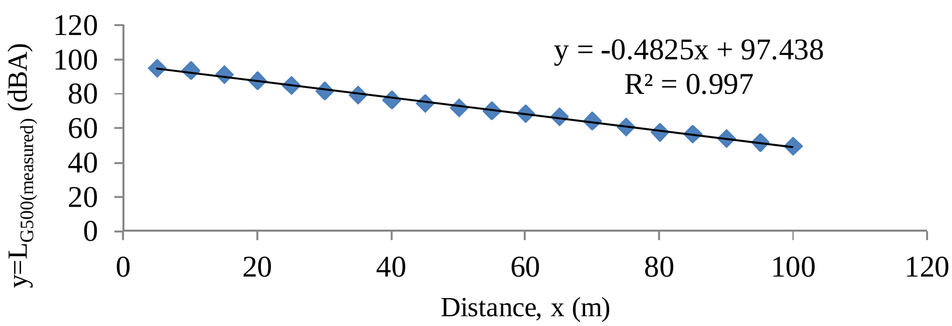

Figure 2: The characteristics of the 500 kVA power generator measured noise level

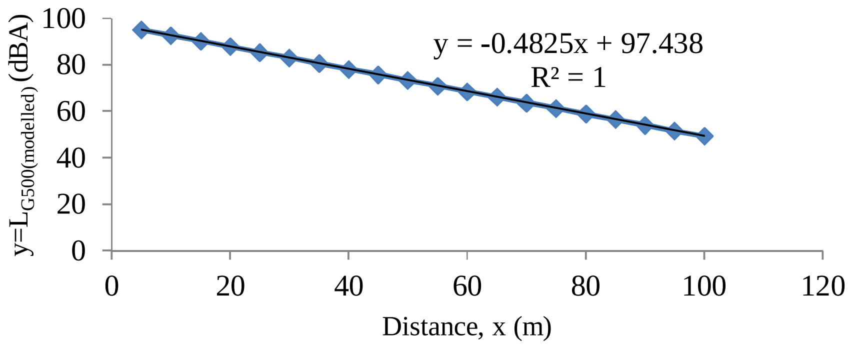

Figure 3: The characteristics of the 500 kVA power generator modeled noise level

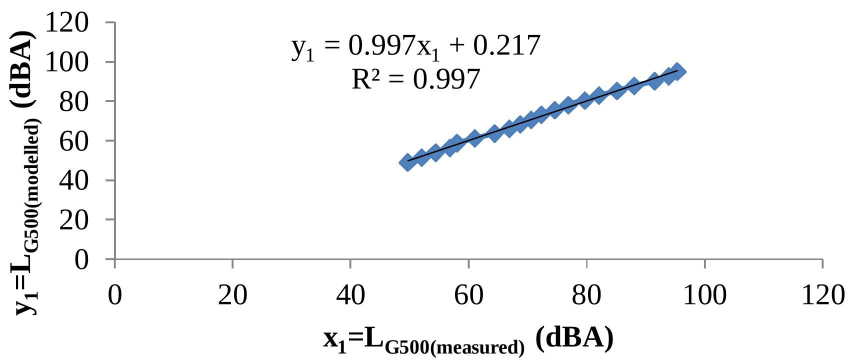

Figure 4: Comparison of modeled noise levels, $L_{G500(modelled)}$and measured noise levels, $L_{G500(measured)}$ of a 500 kVA power generator

Model development for noise levels and distance measurements of a 500 kVA power generator

The results of the analysis of a 500 kVA power generator noise levels, L_{G500} show that the noise levels of the power generator and distance, x are strongly correlated with the coefficient of determination, R^2=0.997. The results of the analysis give a linear fitting model in dBA as presented in equation (4).

$$L_{G500} = 97.43 - 0.482x \quad (4)$$

Considering the error term, ϵ_{G500}, equation (4) becomes

$$L_{G500} = 97.43 - 0.482x + \epsilon_{G500} \quad (5)$$

In equation (4), at$x = 0$, the noise level of the power generator at source is:

$$L_{G500} = 97.43 \text{ dBA.} \quad (6)$$

This value (97.43dBA) represents the intercept or the maximum noise level with a standard error of 0.37 dBA. The model has a slope of –0.482 $dBAm^{-1}$ with a standard error of 0.001 $dBAm^{-1}$. Comparing the predicted noise levels of the power generator, $L_{G500(modelled)}$ with its measured noise levels, $L_{G500(measured)}$ (Figs. 2-4) show that there is no significant difference between them. The coefficient of determination, R^2=0.997 in Fig. 4 also confirms that there is no significant difference between $L_{(measured)}$ and $L_{(modelled)}$.Hence, equation (4) or (5) can be used as a model for evaluating, predicting and controlling environmental noise pollution from a noise source of this type.

The following conditions satisfy the model presented as equation (4):

(I) $0 \leq x_c \leq 87$; at $x_c = 87\,m$, $L_{G500} = 55.46$ dBA

(II) $88 \leq x_s \leq \infty$; at $x_s = 88\,m$, $L_{G500} = 54.98$ dBA

Condition (I) implies that the adverse effects of the noise from the 500 kVA power generator cover distances from 0 m (point of its installation) to 87 m. This is because at a distance of 87 m from the power generator, its noise level is 0.46 dBA greater than the WHO tolerant level of 55 dBA for residential areas. The distance at which the adverse effects covered is denoted by x_c in meters. Condition (II) means that the 500 kVA power generator should be installed or sited from the residential area at a distance of 88 m and above. This is because at the distance of 88 m, the noise level of the power generator is 0.02 dBA less than the WHO recommended level of 55 dBA. Here, x_s is the distance it can be sited in meters (m).

Development of a general model for evaluating, predicting and controlling environmental noise pollution from a 500 kVA power generator

Generally, it is observed that all the models developed in this work are of the forms in equation (7) and equation (8).

$$L_N = -\theta x + \beta \qquad 7$$

$$R^2 = \alpha \qquad 8$$

where, θis the slope representing the attenuation coefficient of the noise from the 500 kVA power generator and it is measured in $dBAm^{-1}$. β is the intercept or the maximum noise level signifying the noise level at source (i.e at $x = 0$) in dBA. x is the distance in metres (m) and α is the coefficient of determination. Substituting equation (7) into equation (2), gives equation (9).

$$L_{eq} = 10\log_{10}\{\frac{1}{T}\{10^{0.1(\beta-\theta x)}\Delta T_N + 10^{0.1L_B}\Delta T_B\}\} \qquad 9$$

Equation (9) shows that when θand β for the 500 kVA power generator are known, L_{eq} of it can be determined at any distance, x with the consideration of the background noise level, L_{B} at that point. Hence, with the introduction of the distance of measurement, x equation (9) can be used as a more scientific and reliable general model for evaluating, predicting and controlling environmental noise pollution from a 500 kVA power generator of this kind. Therefore, this model can be applied in environmental noise impact assessment. L_{eq} is the equivalent continuous noise level. It is measured in dBA.

CONCLUSION

It is concluded from the findings that the equivalent continuous noise level (L_{eq})which is a measure of the energy content of a noise decreases as the distance from the noise source increases and that the maximum noise level of the 500 kVA power generator is (97.44±0.37) dBA. The results indicate that the distances, x_c in meters at which the adverse effects of the generator covered in the residential areas are $0 \leq x_c \leq 87$, while the corresponding distances, x_s in meters in which it can be sited from the residential areas are $88 \leq x_s \leq \infty$. The results of the findings show that the models developed in this work can be used in evaluating and predicting the exact distance at which adverse effects of noise from this generator can cover and in controlling environmental noise pollution from a 500 kVA power generator of this kind. The models require less cost, less manpower and less time than physical measurements. They can be used by the manufacturer of the 500 kVA power generator to reduce its maximum noise level. Hence, the models are recommended to be used as reliable tools for environmental noise impact assessment as the results show insignificant difference between the measured noise levels, $L_{(measured)}$ and the modeled noise levels, $L_{(modelled)}$.

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