THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Estimation of Acoustic Safe Distances for Site of a Cassava Processing Mill from Residential Areas of Nigeria

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Abstract:
Noise from a source like a cassava processing mill degrades the quality of our environment. The distances at which its sound can be tolerated have to be professionally estimated. This work therefore presents estimation of acoustic safe distances for site of a cassava processing mill from residential areas. Hence, measurements of noise levels with respect to distance, x from the cassava processing mill were considered. The linear regression method was used in analysing the data. Environmental noise models were developed by using the relevant displayed parameters. 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 were also compared with the World Health Organisation tolerant levels. The results reveal that the maximum noise level of the Mcassava processing mill is $((107.97\pm0.72)$ dBA. The distances, x_c in metres at which its adverse effects covered in the residential areas are $0 \leq x_c \leq 89$, while the distances, x_s in metres at which it can be sited from the residential areas are $90 \leq x_s \leq \infty$. The results indicate 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 existence of x, the models developed in this work are recommended to be used as more reliable tools for environmental noise impact assessments.

Keywords: Cassava processing mill, distances, estimation, noise level modeling, site

1. Introduction

Noise does affect the inhabitants, humans and fauna, among others in the natural environment. Elevated noise levels of adequate exposure time can result in short-term or permanent hearing damage. This is generally related to those working in industrial plants or operating machinery but can also take place at discotheques or near to aircraft on the ground if the duration is long enough. However, measurable hearing loss from many industrial sounds involves daily exposure for a number of years. On the other hand, community noise intrusions like cassava processing mill noise can obstruct speech communication, interfere with sleep and relaxation and disturb the capacity to perform difficult tasks (Kiely, 1998 and Ekott, 2018).

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. 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. General noise sources are industry, neighbourhoods and traffic. The industrial noise is one of the most annoying sources of noise complaints (Ekott, 2011).

Environmental noise is described by World Health Organisation (WHO) as community noise or residential noise or domestic noise (WHO, 1999). The most important sources of community noise comprise 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 (Ekott, 2018).

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).

In the United States of America, the Environmental Protection Agency (EPA) identified noise as a hindrance since in the 1970s (Menkiti and Ekott, 2014). 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 demeans 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, 2001).

Fairly characteristic road levels of noise are adequate to reduce arterial blood flow and cause elevated blood pressures; in this situation it seems that a specific part of the populace is more vulnerable to vasoconstriction. This may occur because the noise bother leads to high adrenaline intensity to activate vasoconstriction (a reduction of the blood vessels) or separately through reactions from medical stress. Additional impacts of elevated levels of sound are high rate of vertigo fatigue, stomach ulcer and headaches (Ekott, 2011).

Researches 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 metres from residential areas, and 100 metres 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 metres, 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, 2014). 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.

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).

Therefore, thisresearch on noise is very pertinent so asto create more awareness on the impacts of noise on the environment for the betterment of our society. In this research, the estimation of acoustic safe distances for site of a cassava processing mill from residential areas. and the development of models for predicting and controlling environmental noise pollution from a cassava processing mill of this kind shall be carried out.

2. Materials and Methods

2.1. Physical Measurements

Physical measurements of noise levels were made using the sound level meter, modelWensnWS1361 with ½ inch electret condenser microphone. This model has both A and C weightings and 0.1dB resolution with fast/slow response. It has a measuring range 30 to 130 dBA or 35 to 130 dBC. Also, 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 analyser level recorder, Fast Fourier Transform (FFT) analyser, 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. The manufacturer's manual gave the calibration procedure. During the noise level measurements, the microphone of the sound level meter was positioned at a distance of 5 m from the cassava processing mill at a height of 1.2 m above the ground and windshield was always used for accuracy. Slow response was used for comparatively stable noise measurement. For instance, 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 the 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).

2.2. Noise Level with Distance Measurements

In this case, a cassava processing mill was identified. 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 earlier, while distance measurements were made using a measuring tape. Lastly, L_{eqs} for it were evaluated.

2.3. 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 equations (1-2) and it is measured in dBA.

$$L_{Aeq} = 10 \log_{10}[\frac{1}{T} \int_0^T \frac{P(t)^2}{P_0^2} dt] \qquad\qquad 1$$

$$L_{Aeq} = 10 \log_{10}(\frac{1}{T} \int_0^T 10^{0.1L_i} dt) \qquad\qquad 2$$

where,

T   = time period over which L_{Aeq} is determined
P(t)   = the instantaneous A-weighted sound pressure
P_o = the reference sound pressures (20 µPa)
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 (3) (Kiely, 1998; Ekott *et al.,* 2018; Ekott and Essien, 2019).

$$L_{eq} = 10 \log_{10}\{\frac{1}{T}\{10^{0.1L_N}\Delta T_N + 10^{0.1L_B}\Delta T_B\}\} \qquad\qquad 3$$

The noise level of a noise source, L_N is presented in equation (4) (Cunniff, 1977; Kiely, 1998; Ekott *et al.,* 2018; Ekott and Essien, 2019).

$$L_N = 10 \log_{10}(10^{0.1L_{TOTAL}} - 10^{0.1L_B}) \qquad\qquad 4$$

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

2.4. Noise Modelling

The data obtained were analysed 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. The results are presented in section 3.

3. Results and Discussion

3.1. Analysis of Noise Levels and Distance Measurements from the Cassava Processing Mill

The results of the survey (Table 1-2 and Figures1-4) reveal that the noise of the cassava processing mill can cause serious annoyance up to distances of about 80 – 90 metres. At a distance of 80 metres, the respective approximate annoying noise level with cassava mill, cassava mill noise level alone and the equivalent continuous noise level are 60.4 dBA, 60.4 dBA and 56.4 dBA which are above the WHO safety level of 55 dBA for a non-work place. The values of the background noise levels indicate that the area is conducive for residents when the noise of the cassava is absent. The workers should be advised to wear ear protector and the duration of exposure should be professionally managed.

Distance, x (m)	Background noise level (dBA)	Noise level at cassava mill (dBA)	Cassava mill noise level (dBA)	Equivalent continuous noise level, L_{eq} (dBA)
5	40.1	104.6	104.5999985	100.6206007
10	40.0	102.4	102.3999975	98.42060116
15	39.9	100.0	99.99999576	96.02060204
20	39.2	96.8	96.79999245	92.82060369
25	39.4	93.6	93.59998349	89.62060817
30	39.7	91.4	91.39997064	87.42061459
35	39.3	88.2	88.19994405	84.22062789
40	38.6	85.4	85.39990926	81.42064528
45	39.0	81.0	80.99972597	77.02073692
50	37.9	77.1	77.09947783	73.12086097
55	38.8	74.7	74.69888355	70.72115803
60	40.3	68.5	68.49342171	64.52388533
65	39.8	66.6	66.59091681	62.62513439
70	38.7	64.9	64.88956949	60.92580579
75	38.9	62.3	62.28010340	58.33051413
80	37.9	60.4	60.37550890	56.43279387
85	38.0	58.9	58.86455497	54.93821453
90	38.4	56.1	56.02561277	52.15732112
95	40.2	53.7	53.50154162	49.81652872
100	39.6	50.3	49.91367075	46.50159759

Table 1: Noiselevels and Distance Measurements from the Cassava Processing Mill
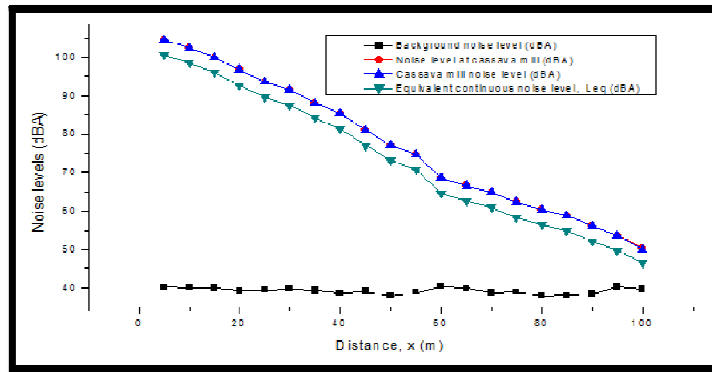
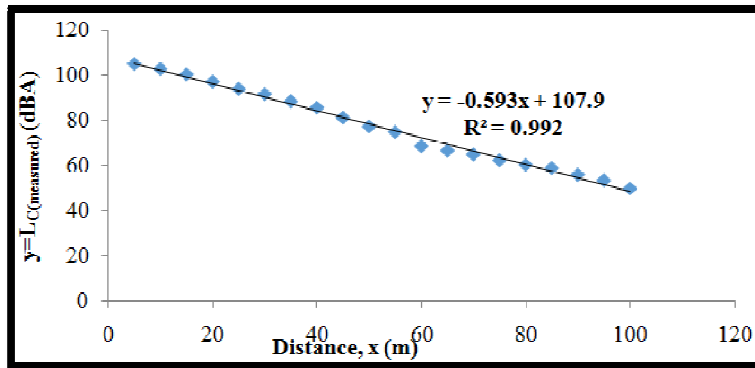Figure 1: The Cassava Processing Mill Noise Levels against Distance

Figure 2: The Characteristics of the Cassava Processing Mill Measured Noise Level

3.2. Model Development of Noise Levels and Distance Measurements for the Cassava Processing Mill

The results of the analysis of the noise levels of a cassava processing mill show that the noise levels of the cassava processing mill, L_C and distance, x are strongly correlated with the coefficient of determination, R^2=0.99222. The linear fitting model in dBA deduced from the analysis is presented in equation (5).

$$L_C = 107.97329 − 0.59365x \qquad\qquad 5$$

Introducing the error term, ϵ_C, equation (5) becomes

$$L_C = 107.97329 − 0.59365x + \epsilon_C \qquad\qquad 6$$

In equation (5), if $x = 0$, the noise level of the cassava processing mill at source is:

$$L_C = 107.97329 \text{ dBA} \qquad\qquad 7$$

Equation (7) gives the intercept or the maximum noise level with a standard error of 0.72233 dBA. The model has a slope of –0.59365 dBAm^{-1} with a standard error of 0.01206 dBAm^{-1}. Comparing the predicted noise levels of the cassava processing mill, $L_{C(modelled)}$ with its measured noise levels, $L_{C(measured)}$ (Table 2 and Figures 2-4) certainly reveal that there is no significant difference between $L_{C(modelled)}$ and $L_{C(measured)}$. This means that $L_{C(modelled)}$ and $L_{C(measured)}$ are strongly correlated. Therefore, equation (5) or (6) can be employed as a model for evaluating, predicting and controlling environmental noise pollution from a cassava processing mill of this kind.

The following conditions satisfy the model presented as equation (5):

$0 \leq x_c \leq 89$; at $x_c = 89\ m$, $L_C = 55.13844$ dBA

$90 \leq x_s \leq \infty$; at $x_s = 90\ m$, $L_M = 54.54479$ dBA

Condition (I) implies that the adverse effects of the noise from the cassava processing mill cover distances from 0 m (point of its installation) to 89 m. This is because at a distance of 89 m from the cassava processing mill, its noise level is 55.13844 dBA instead of the WHO tolerant level of 55 dBA for residential areas. The distance at which the adverse effects covered is denoted by x_c in metres. Condition (II) means that the cassava processing mill should be operated or sited from the residential area at a distance of 90 m and above. This is because at the distance of 90 m, the noise level of the cassava processing mill is 54.54479 dBA, which is less than the WHO recommended level of 55 dBA. Here, x_s is the distance it can be sited in metres (m).
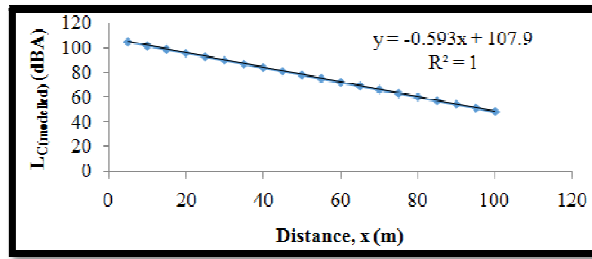
Figure 3: The Characteristics of the Cassava
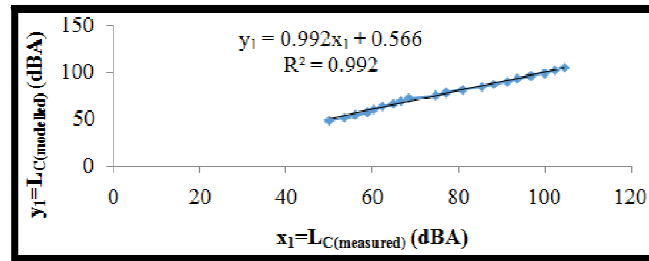Processing Mill Modelled Noise Level

Figure 4: Comparison of Modelled Noise Levels, $L_{C(Modelled)}$ and Measured Noise
Levels, $L_{C(Measured)}$ of the Cassava Processing Mill

Distance, x (m)	$L_{C(measured)}$ (dBA)	$L_{C(modelled)}$ (dBA)	$L_{C(difference)}$ (dBA)
5	104.6000	105.0050	-0.4050
10	102.4000	102.0368	0.3632
15	100.0000	99.0685	0.9315
20	96.8000	96.1003	0.6997
25	93.6000	93.1320	0.4679
30	91.4000	90.1638	1.2362
35	88.1999	87.1955	1.0044
40	85.3999	84.2273	1.1726
45	80.9997	81.2590	-0.2593
50	77.0995	78.2908	-1.1913
55	74.6989	75.3225	-0.6237
60	68.4934	72.3543	-3.8609
65	66.5909	69.3860	-2.7951
70	64.8896	66.4178	-1.5282
75	62.2801	63.4495	-1.1694
80	60.3755	60.4813	-0.1058
85	58.8646	57.5130	1.3515
90	56.0256	54.5448	1.4808
95	53.5015	51.5765	1.9250
100	49.9137	48.6083	1.3054

Table 2: Comparison of Predicted Noise Levels, $L_{c(Modelled)}$ and Measured
Noise Levels, $L_{c(Measured)}$ of the Cassava Processing Mill

3.3. Development of a General Model for Evaluating, Predicting and Controlling Environmental Noise Pollution from the Cassava Processing Mill

It is observed that all the models developed in this work are of the forms in equation (8) and equation (9).

$$L_N = -\theta x + \beta \qquad\qquad 8$$
$$R^2 = \alpha \qquad\qquad 9$$

where, θ is the slope representing the attenuation coefficient of the noise from the cassava processing mill 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 (8) into equation (3), gives equation (10).

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

Equation (10) shows that when θ and β for the cassava processing mill are known, its L_{eq} 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 (10) can be used as a more scientific and reliable general model for evaluating,

predicting and controlling environmental noise pollution from sources. Therefore, this model can be applied in environmental noise impact assessment. L_{eq} is the equivalent continuous noise level. It is measured in dBA.

4. Conclusion

In conclusion:

- The equivalent continuous noise level (l_{eq})decreases as the distance from the cassava processing mill increases;
- the maximum noise levels of the cassava processing mill are (107.97±0.72) dba;
- The distances, x_c in metres at which the its adverse effects covered in the residential areas are $0 \leq x_c \leq 89$;
- the distances, x_s in metres at which the cassava processing mill can be sited from the residential areas are $90 \leq x_s \leq \infty$;
- All the models developed in this work can be used in evaluating, predicting and controlling environmental noise pollution from a cassava processing mill of this kind; they require less cost, less manpower and less time than physical measurements; they can be used by the manufacturer of the noise generating equipments to reduce their maximum noise levels; they can be used to predict the exact distance at which adverse effects of noise from a source can cover and
- 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 modelled noise levels, $l_{(modelled)}$.

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