

Prediction of safe operating distances for a 1 horse power (1 hp) chainsaw in non-work environment

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Abstract: Noise from a source like a chainsaw mortifies the value of our environment. Noise is known to produce many adverse effects both on humans and on structures. The distances at which the adverse effects of noise from a 1 hp chainsaw cover in the residential areas must be predicted. This work therefore presents prediction of safe operating distances for a 1 hp chainsaw in a non-work environment. Measurements of noise levels with respect to distance, x from the 1 hp chainsaw in operation were considered. The linear regression method was used in analysing the data. Environmental noise models were developed by using the relevant displayed parameters. Then, the results obtained from the models developed in this work, $L_{H(\text{modelled})}$ were compared with the results obtained from the physical measurements, $L_{H(\text{measured})}$. The results revealed that the maximum noise level of a 1 hp chainsaw were (121.07 ± 1.52) dBA. The corresponding distances, x_c in metres at which its adverse effects covered in the residential areas were $0 \leq x_c \leq 90$. The distances, x_s in metres in which it can be operated from the residential areas were $91 \leq x_s \leq \infty$. 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 $L_{H(\text{measured})}$ and $L_{H(\text{modelled})}$. 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: a 1 hp chainsaw, operating distances, modeling, non-work environment, prediction

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I. Introduction

Residential noise is described as community noise or environmental noise or domestic noise [1]. 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 [2].

In the United States of America, the Environmental Protection Agency (EPA) identified noise as a hindrance since in the 1970s [3]. 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 [4].

In this context, noise is defined as unpleasant sound [5]. 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 [2]. 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. General noise sources are industry, neighbourhoods and traffic. The industrial noise is one of the most annoying sources of noise complaints [6].

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 [7]. 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 dysgraphia is usually related to stress on environment during classes [8]; [9]. 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 [10]. 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 [6].

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 [11]. Researches have shown that constant noise above 55 dBA causes serious annoyance and above 50 dBA moderate annoyance at home [12]. 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 [1]. 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 [3]. 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 prediction of safe operating distances for a 1 hp chainsaw in a non-work environment. and the development of models for predicting and controlling environmental noise pollution from a chainsaw of this kind shall be carried out.

II. Materials And Methods

2.1 Physical measurements

The noise level measurements were made using the sound level meter (SLM), model WensnWS1361 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 [13].

2.2 Noise level with distance measurements

In this case, a workshop/factory with a 1 hp chainsaw 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 above, while distance measurements were made using a measuring tape. Lastly, L_{eqs} for it were calculated.

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.

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

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

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 μ Pa)

L_i = noise level in the i th 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) [14]; [15].

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

The noise level of a noise source, L_N is presented in equation (4) [16]; [14]; [15].

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

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 used. 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 sections 3.

III. Results And Discussion

3.1 Analysis of noise levels and distance measurements from a 1 horse power (1 hp) chainsaw

The results of the survey (Table 1 and Figure.1) reveal that the chainsaw noise was heard beyond a distance of 100 metres. At the distance of 100 metres, the background noise level is 39.8 dBA, while the respective approximate levels of total noise, chainsaw noise and L_{eq} are 52.6 dBA, 52.4 dBA and 48.7 dBA. With the annoying noise of the chainsaw, it should not be operated around the residential areas. The chainsaw operator should be advised to wear ear protectors. Also, the duration of exposure should be professionally considered.

Table 1: Noise levels and distance measurements from a 1 hp chainsaw

Distance, x (m)	Background noise level (dBA)	Noise level with chainsaw (dBA)	Chainsaw noise level (dBA)	Equivalent continuous noise level, L_{eq} (dBA)
5	37.7	119.2	119.20000000	115.22059990
10	38.0	115.6	115.59999990	111.62060000
15	38.2	113.9	113.89999990	109.92060000
20	36.5	108.3	108.29999970	104.32060010
25	37.4	104.8	104.79999920	100.82060030
30	36.9	99.1	99.09999738	95.12060122
35	35.8	94.6	94.59999427	90.62060278
40	36.6	91.4	91.39998562	87.42060710
45	36.3	87.6	87.59996781	83.62061601
50	37.7	83.0	82.99987183	79.02066400
55	35.0	76.9	76.89971959	72.92074011
60	36.8	71.2	71.19842289	67.22138826
65	36.0	68.8	68.79772019	64.82173937
70	37.9	68.2	68.19594504	64.22262598
75	37.6	62.7	62.68655824	58.72730523
80	39.0	63.0	62.98267592	59.02923611
85	38.1	62.1	62.08267592	58.12923611
90	40.5	59.4	59.34368853	55.44848419
95	41.2	56.9	56.78150623	52.97865607
100	39.8	52.6	52.36588044	48.73309087

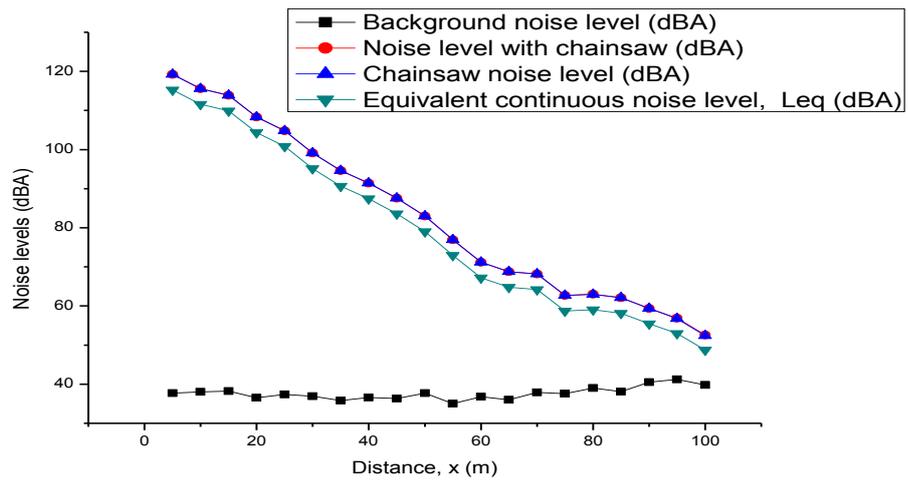


Figure 1: A 1 hp chainsaw noise levels against distance

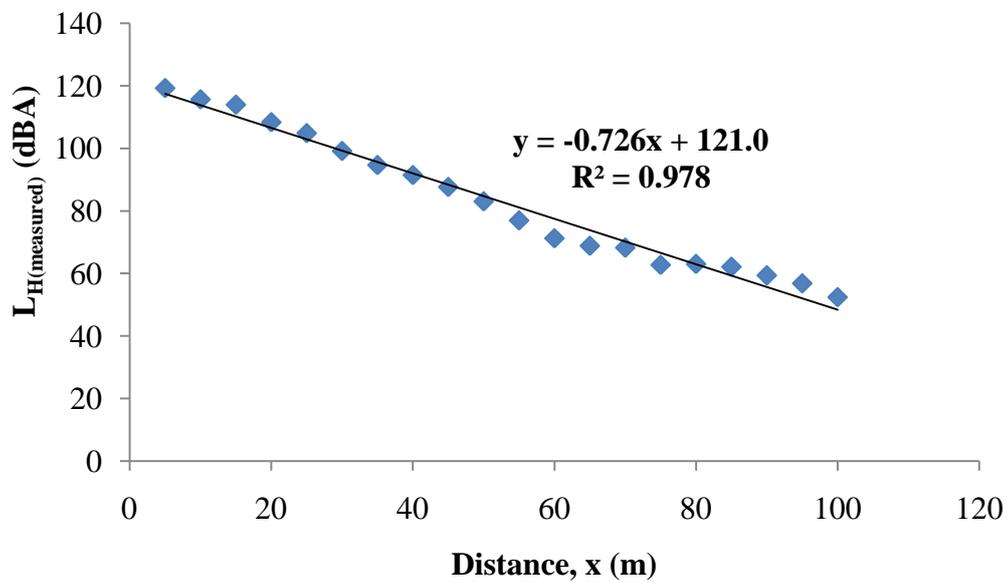


Figure 2: The characteristics of the 1 hp chainsaw measured noise level

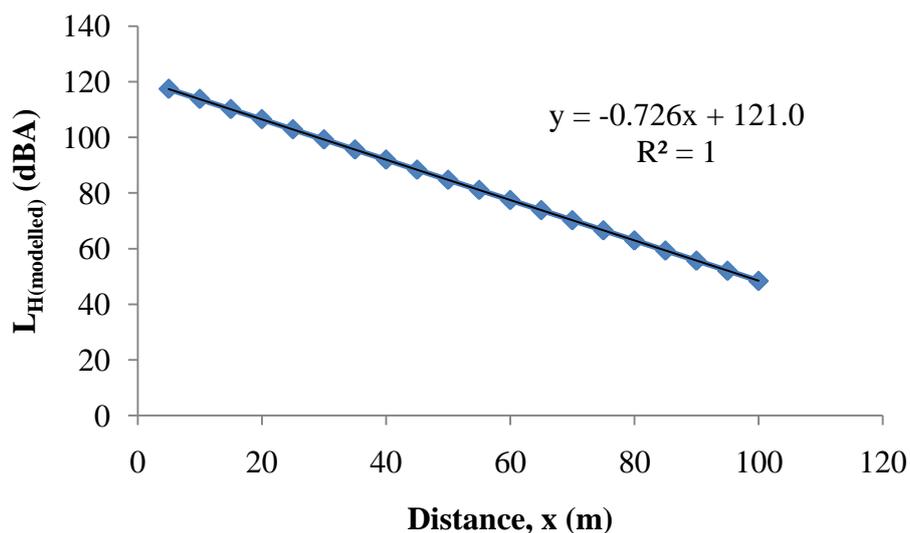


Figure 3: The characteristics of the 1 hp chainsaw modelled noise level

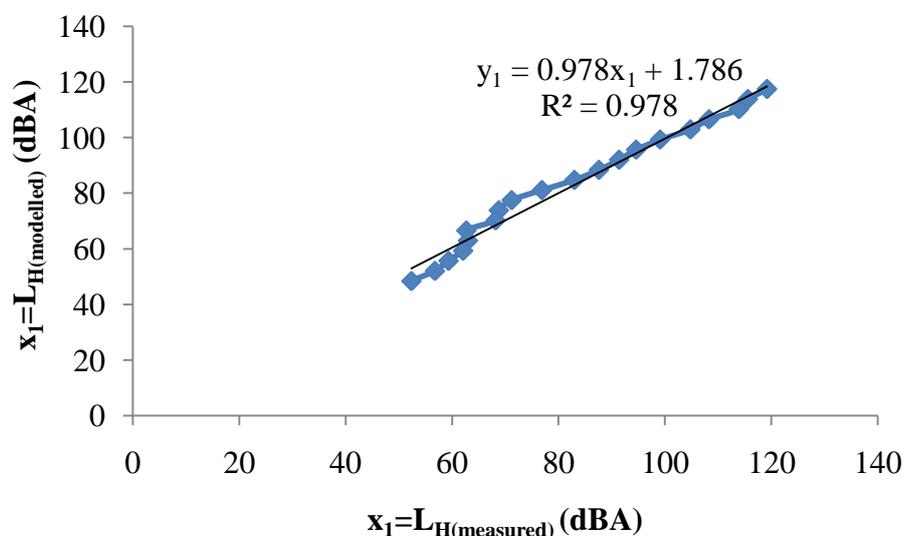


Figure 4: Comparison of modelled noise levels, $L_{H(\text{modelled})}$ and measured noise levels, $L_{H(\text{measured})}$ of a 1 hp chainsaw

3.2 Model development of noise levels and distance measurements for a 1 hp chainsaw

The results of the analysis of the noise levels of a 1 hp chainsaw show that the noise levels of the chainsaw, L_H and distance, x are strongly correlated with the coefficient of determination, $R^2=0.97727$. The linear fitting model in dBA deduced from the analysis is presented in equation (5).

$$L_H = 121.07164 - 0.72628x \quad 5$$

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

$$L_H = 121.07164 - 0.72628x + \epsilon_H \quad 6$$

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

$$L_H = 121.07164 \text{ dBA} \quad 7$$

Here, the intercept or the maximum noise level is 121.07164 dBA with a standard error of 1.52096 dBA. The model has a slope of $-0.72628 \text{ dBAm}^{-1}$ with a standard error of $0.02572 \text{ dBAm}^{-1}$. Comparing the modelled noise levels of the chainsaw, $L_{H(\text{modelled})}$ with its measured noise levels, $L_{H(\text{measured})}$ (Table 2 and Figures 2-4), it was indicated that there is no significant difference between them. The slight difference is attributed to the fact that the chainsaw generated fluctuating sound. This reveals that $L_{H(\text{modelled})}$ and $L_{H(\text{measured})}$ are strongly correlated. Hence, equation (5) or equation (6) can be used as a model for evaluating, predicting and controlling environmental noise pollution from a chainsaw of this nature.

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

(I) $0 \leq x_c \leq 90$; at $x_c = 90$ m, $L_H = 55.70644$ dBA

(II) $91 \leq x_s \leq \infty$; at $x_s = 91$ m, $L_H = 54.98016$ dBA

Condition (I) implies that the adverse effects of the noise from the 1 hp chainsaw cover distances from 0 m (point of its installation) to 90 m. This is because at a distance of 90 m from the chainsaw, its noise level is 55.70644 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 1 hp chainsaw should be operated or sited from the residential area at a distance of 91 m and above. This is because at the distance of 91 m, the noise level of the power generator is 54.98016 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).

Table 2: Comparison of modelled noise levels, $L_{H(\text{predicted})}$ and measured noise levels, $L_{H(\text{measured})}$ of the 1 hp chainsaw

Distance, x (m)	$L_{H(\text{measured})}$ (dBA)	$L_{H(\text{modelled})}$ (dBA)	$L_{H(\text{difference})}$ (dBA)
5	119.2000	117.4402	1.7598
10	115.6000	113.8088	1.7912
15	113.9000	110.1774	3.7226
20	108.3000	106.5460	1.7540
25	104.8000	102.9146	1.8854
30	99.1000	99.2832	-0.1832
35	94.6000	95.6518	-1.0518
40	91.4000	92.0204	-0.6204
45	87.6000	88.3890	-0.7890
50	82.9999	84.7576	-1.7577
55	76.8997	81.1262	-4.2265
60	71.1984	77.4948	-6.2964
65	68.7977	73.8634	-5.0657
70	68.1959	70.2320	-2.0361
75	62.6866	66.6006	-3.9140
80	62.9827	62.9692	0.0135
85	62.0827	59.3378	2.7449
90	59.3437	55.7064	3.6373
95	56.7815	52.0750	4.7065
100	52.3659	48.4436	3.9223

3.3 Development of a general model for evaluating, predicting and controlling environmental noise pollution from the 1 hp chainsaw

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

$$L_N = -\theta x + \beta \tag{8}$$

$$R^2 = \alpha \tag{9}$$

where, θ is the slope representing the attenuation coefficient of the 1 hp chainsaw 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).

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

Equation (10) shows that when θ and β for a particular noise source are known, L_{eq} of the noise source 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 a 1 hp chainsaw 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.

IV. Conclusion

It is concluded from the findings that:

- (i) the equivalent continuous noise level (L_{eq}) decreases as the distance from the chainsaw increases;
- (ii) the maximum noise level of the 1 hp chainsaw is (121.07 ± 1.52) dBA;
- (iii) the distances, x_c in metres at which its adverse effects covered in the residential areas are $0 \leq x_c \leq 90$;
- (iv) the safe distances, x_s in metres in which the chainsaw can be operated from the residential areas are $91 \leq x_s \leq \infty$;
- (vi) all the models developed in this work can be used in evaluating, predicting and controlling environmental noise pollution from a 1 hp chainsaw of this kind; they require less cost, less manpower and less time than physical measurements; they can be used by the manufacturer of the 1 hp chainsaw to reduce its maximum

noise levels; they can be used to predict the exact distance at which adverse effects of noise from chainsaw can cover and

- (vii) 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, $L_{H(\text{measured})}$ and the modelled noise levels, $L_{H(\text{modelled})}$.

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