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Modeling Sawmill Noise Induced Hearing Deterioration

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ABSTRACT: Sawmill noise induced hearing deterioration has been modelled using measured noise levels at selected sawmills (Rumuosi, Ogbogoro and Mile 3) in Port Harcourt. Noise measurement was taken for one hour at six-minute interval using a Sound Level Meter and conducted three times daily (morning, afternoon and evening) for five days at each sawmill. Background noise at the studied sawmills ranged 53.68 – 56.92 dBA in the order of Mile 3 > Rumuosi > Ogbogoro. Equivalent continuous noise levels (L_{eq}) ranged83.37 – 87.03 dBA (Rumuosi), 85.10 – 86.48dBA (Ogbogoro) and 85.38 – 86.46 dBA (Mile 3). Although these L_{eq} values are less than the recommended standard of 90 dB per 8 hours daily, persistent exposure without ear protection could still result to devastating health effect on receptors. Thus, from the L_{eq} results, hearing deterioration prediction models were developed for the three studied sawmills with coefficient of determination (R^2) range of 0.966 – 0.986 and p-value range of 0.999927 – 0.999999 ($p>0.05$), indicating excellent fit. Therefore, it is concluded that the developed models can adequately predict hearing deterioration due to exposure to the noise from the studied sawmills.
KEYWORDS: Sawmill noise, Modeling, Induced hearing deterioration, Sound level meter

I. INTRODUCTION

Noise is a significant environmental pollutant and considered to be the third most hazardous type of pollution by the World Health Organization [1]. Exposure to excessive noise has negative impacts on the victims. The most common being hearing impairment in which the ability of the individual to hear and participate in conversation is greatly reduced [2]. Apart from hearing impairment, there are also other negative effects of excessive noise exposure being physiological and psychological problems [3-4]. It has the potentials to annoy, awaken, anger and frustrate people. It disrupts communication and individual thoughts, and affects performance capability. This is generally associated with those working in industrial plants or operating machineries like in sawmills.

Noise pollution in several industrial workplaces have been extensively studied. Some of these studies investigated noise pollution in sawmills, printing presses, corn mills, oil mills, textile factories, integrated steel plants, feed mills, construction sites and combination of industrial sites [3-10]. The noise level reported by these studies with diverse machineries and operating environments varied considerably. Until now, there is a dearth of knowledge on the hearing deteriorating effect of noise from Rumuosi, Ogbogoro and Mile 3 sawmills hence the need for this study.

Since the ancient civilization, woodwork has been useful to human society and continues to play a major role in the world as its demand is greatly on the increase [11]. Sawmills where logs are processed have been reported to be an extreme acoustic environment for workers [12]. Since sawmills have become relevant to our modern society, its number has increased drastically, with some even located in residential areas, making it necessary for studies on the hearing deteriorating effect of its noise to be conducted. In this study, equivalent continuous noise associated with sawmilling activities in selected sawmills in Port Harcourt was measured and the results obtained was used to develop a model for predicting the possible hearing impairment with time on exposed workers.

II. MATERIALS AND METHODS

2.1 Study Area

Mile 3, Ogbogoro and Rumuosi sawmills were purposefully selected for this study (Fig. 1). Mile 3, a densely populated business area is located in Diobu, Port Harcourt Local Government Area, Rivers State. Ogbogoro and Rumuosi are located in Obio-Akpor Local Government Area, Rivers State. Both Port Harcourt Local Government Area and Obio-Akpor Local Government Area largely make up the Port Harcourt City. The geographical coordinates of these sawmills are 4º47′24″ N and 6º59′36″ E (Mile 3 sawmill), 4º50′48″ N and 6º55′50″ E (Ogbogoro sawmill), 4º53′05″ N and 6º55′36″ E (Rumuosi sawmill). In these sawmills, logs are broken down into specified sizes and shapes. The machines used to carry out this operation are Stenner machine, Planing machine, Table saw and Sharpening machine. Although, Rumuosi and Mile 3 sawmills have additional machine known as the Design machine. An additional activity carried out in these sawmills is the trading of the finished product and saw dust (a by-product of sawmilling activity). The machines mentioned are used either simultaneously or consecutively depending on the nature and volume of work being carried out. These sawmills operate six days in a week (Monday to Saturday) and about 10 hours per day (8am – 6pm). The age ranges of the machines used in these sawmills are between 8 to 11 years (Mile 3 sawmill), 9 to 13 years (Rumuosi sawmill) and 8 to 12 years (Ogbogoro sawmill). The frequency at which the machines are used is dependent on the availability of raw material. Other intrusive noise sources were identified and considered during measurements at each sawmill. Throughout the assessment period, it was observed that the workers worked without appropriate personal protective equipment (PPE).

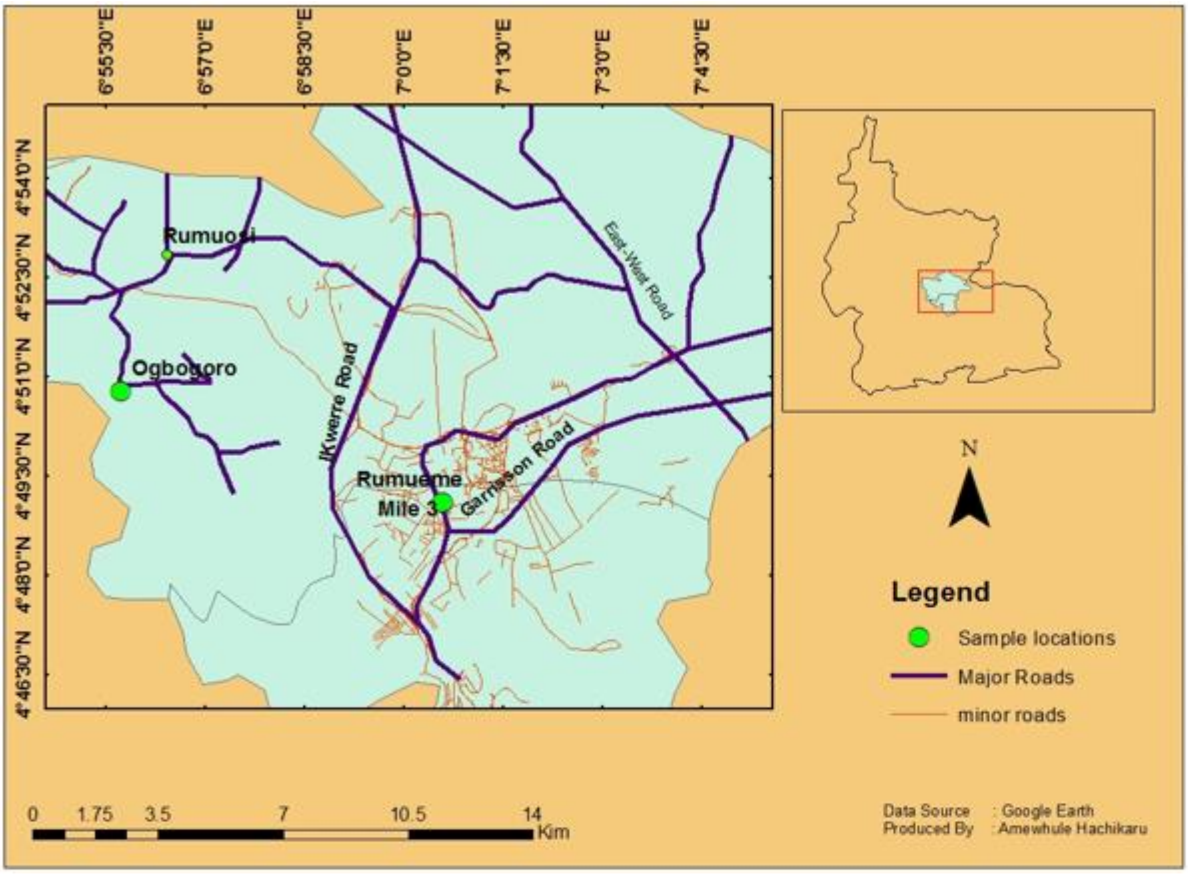

Fig. 1: Locations of studied sawmills

2.2 Noise Measurements

Noise levels in A-weighted decibel were measured from the different sawmills using a Sound Level Meter (SLM), with model number SL-5868P, which gives instant real time equivalent continuous sound level (L_{eq}) readings. The desired response of the SLM was set at fast with range of 30 – 130dB. The noise measurement was taken at six-minute interval for one hour. This was done three times daily (morning, afternoon and evening) for 5 days at each sawmill. The same method of measurement was adopted for the background noise. The SLM was held at 1.5m from the ground in accordance with the Canadian Centre for Occupational Health and Safety noise measurement procedure for standing working position.

2.3 Estimation of Hearing Deterioration Index

Hearing deterioration index (HDI), a tool used in measuring noise induced hearing loss, was calculated using Equation (1)

$$\text{HDI} = 10 \log_{10}\left(\int_0^t 10^{L/20} dt\right) \quad (1)$$

where L is the average continuous noise level in dBA and t is the observation time. HDI represents the Hearing Deterioration Index.

2.4 Model Development

Independent variables such as equivalent continuous noise level (L_{eq}) and time of exposure (T) where regressed to develop a model predicting the HDI for each sawmill. Multiple linear regression was adopted and given by the general expression:

$Y = a + bL_{eq} + cT$ (2)

where Y represents the HDI and a, b and c are constants which depend on sawmill machines and location, L_{eq} is the equivalent continuous noise level which varies with sawmills, and T is the time of exposure.

Three normal equations were generated and solved using Microsoft excel data analysis tool pak.

$\sum Y = na + b\sum L_{eq} + c\sum T$ (3)

$\sum YL_{eq} = a\sum L_{eq} + b\sum L_{eq}^2 + c\sum TL_{eq}$ (4)

$\sum YT = a\sum T + b\sum L_{eq}T + c\sum T^2$ (5)

where n is the number of data, a, b, c, T and L_{eq} are as defined earlier.

III. RESULTS AND DISCUSSION

3.1 Background Noise Level

The average background noise levels of the three studied sawmills are presented in Fig.2. The background noise levels of all sawmills are below the Federal Ministry of Environment (FMEnv.) recommended day time standard of 60dBA for residential and small scale production and commerce [13]. Among the studied sawmills, the background noise level is in the order of Mile 3 sawmill > Rumuosi sawmill > Ogbogoro sawmill. This order is the same for all measurement periods (morning, afternoon and evening). The variation in the background noise of the three studied sawmills can be attributed to the location and population of their respective host communities. In a similar study, Ugwoha et al. [14] obtained higher values of background noise levels as opposed to the result presented in this study. The results obtained by the researchers still varied with respect to location. The higher background noise level obtained by Ugwoha et al. [14] could be attributed to the difference in time of study, as background noise level is time dependent.

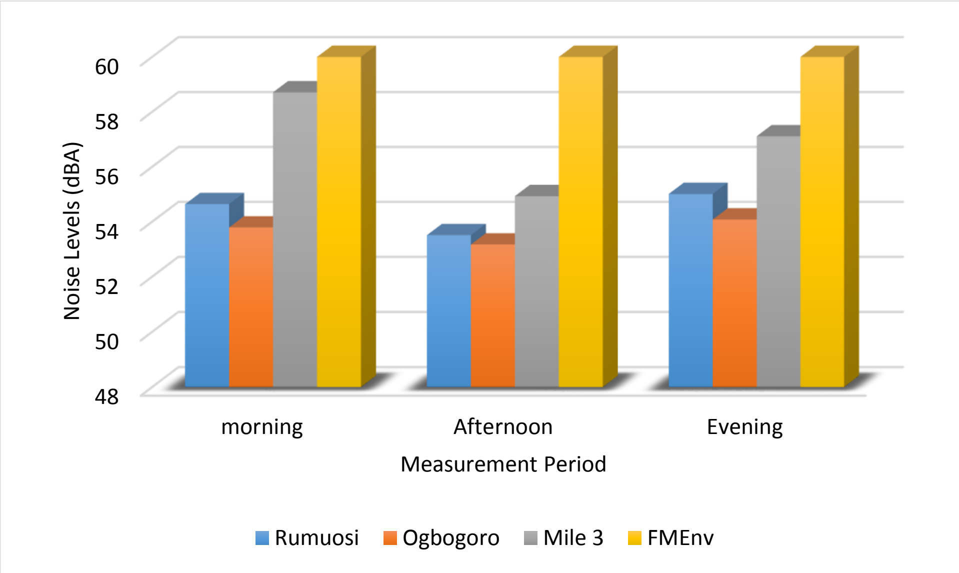

Fig. 2: Background noise levels of the studied sawmills

3.2 Equivalent Continuous Noise Levels (L_{eq})

Figure 3 presents the average L_{eq} values at the studied sawmills. Average L_{eq} values ranged 83.37 – 87.03dBA (Rumuosi sawmill), 85.10 – 86.48dBA (Ogbogoro sawmill) and 85.38 – 86.46dBA (Mile 3 sawmill). The lowest L_{eq} values were recorded in the morning for all sawmills while the highest L_{eq} values were recorded in the evening (Rumuosi sawmill) and afternoon (Ogbogoro and Mile 3 sawmills). The lowest L_{eq} values in the morning at all sawmills is because fewer machines are turned on during the morning hours. This is a common phenomenon among the studied sawmills because the planing and stenner machines are dependent on the table saw, hence cannot be turned on in the morning until the table saw has prepared appropriate number of woods.

The average noise levels produced at the studied sawmills (Fig. 3) shows that all fell below the FMEnv. and OSHA recommended standard of 90dBA for 8 hours. However, continuous exposure to noise greater than or equal to 85dBA can lead to harmful health effect, if ear protection is not used. Ugbebor and Yorkor [15] in a similar study obtained average L_{eq} of 97.88 dB, 98.02 dB and 96.24 dB for Rumuosi sawmill, Mile 1 sawmill and Mile 3 sawmill respectively, contrary to 85.48 dB, 85.78 dB and 86.01 dB presented in this research for Rumuosi sawmill, Ogbogoro sawmill and Mile 3 sawmill respectively. This difference can be attributed to the different noise measuring instruments used for the studies. Ugbebor and Yorkor [15] used smart sensor (AR854) and TES (1352H) while this study used SLM (SL-5868P). Also, the method of measurement can be a factor causing the difference in results. Ugbebor and Yorkor [15] adopted a continuous noise measurement procedure while this study adopted an intermittent noise measurement procedure.

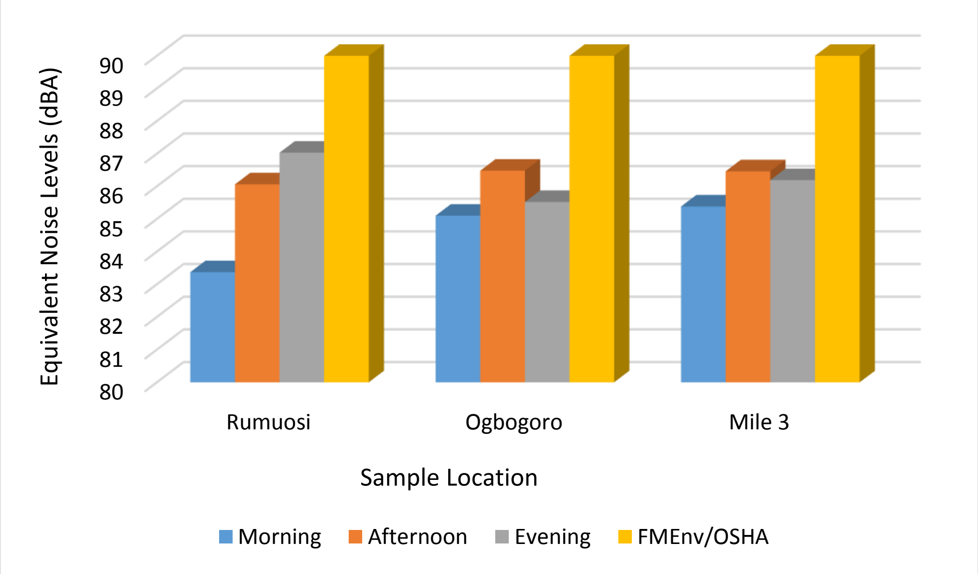

Fig. 3: Measured L_{eq} of the studied sawmills

3.3 Predictive Model for HDI

Table 1 shows the mathematical relationships for the prediction of HDI for each sawmill. This models were developed by testing a multiple linear regression model using respective daily L_{eq} for each sawmill and a common time of exposure (T). Although the models have a common root, they differ. This is due to the variation in L_{eq} measured for the various sawmills. Thus, the models in Table 1 are sawmill specific models which may depend on the location of sawmill, brand and age of the machines used in sawmills.

Table 1: Predictive model for HDI in the studied sawmills

Sawmill	HDI predictive model
Rumuosi	$HDI = 81.60235 - 0.36641\, L_{eq} + 0.\ 23532\, T$
Ogbogoro	$HDI = -54.0714 + 1.241754\, L_{eq} + 0.\ 151219\, T$
Mile 3	$HDI = 6.672708 + 0.528185\, L_{eq} + 0.\ 170714\, T$

3.4 Model Validation

Figures 4 - 6 show the measured and predicted HDI values for the studied sawmills. The high coefficient of determinations ($R^2 > 0.96$) obtained in all cases indicate good agreement between the measured and predicted HDI. More so, the p-values ($p > 0.99$) obtained from one-way ANOVA at 5% level of significance in all cases imply that there is no significant difference between the measured and predicted HDI. Thus, the models generated for each sawmill gave an excellent fit to their respective data.

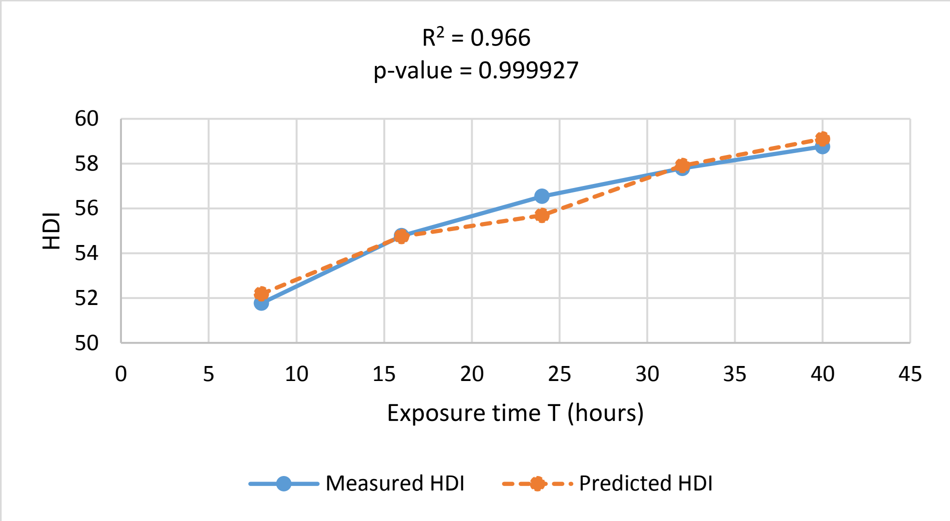

Fig. 4: Measured and predicted HDI for Rumuosi sawmill

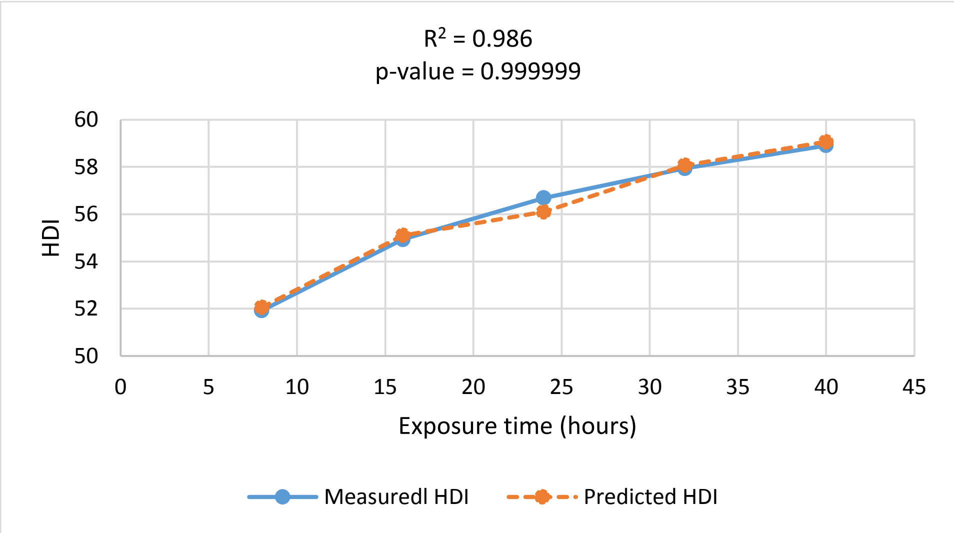

Fig. 5: Measured and predicted HDI for Ogbogoro sawmill

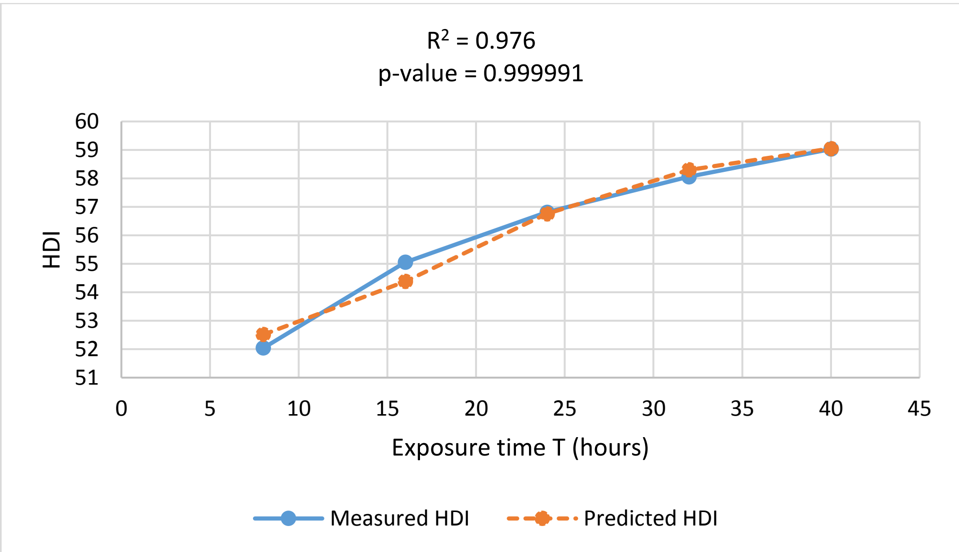

Fig. 6: Measured and predicted HDI for Mile 3 sawmill

IV. CONCLUSION

The noise levels at three sawmills have been measured in order to model their noise induced hearing deterioration on the workers. The measured equivalent continuous noise levels (L_{eq}) which ranged 83.37 – 87.03 dBA (Rumuosi), 85.10 – 86.48 dBA (Ogbogoro) and 85.38 – 86.46 dBA (Mile 3) were used to develop the individual noise induced hearing deterioration prediction model for each of the three studied sawmills. Although the models have a common root, they differ significantly due to variation in L_{eq} at the different sawmills. The excellent fit of the models to their respective data indicate that such models can be used to closely monitor the noise induced hearing deterioration of sawmill workers.

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