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The Effect of Noise Pollution Due to Burr Mills Grinders on their Operators

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ABSTRACT

Burr mill grinders are one of the major noise pollutants in Nigerian communities - in the cities and the villages as well. Those living close to the burr mill grinders' installations and especially their operators are noticeably and negatively aggressive in their social lifestyles. Quantifying and linking this behavioural attitude to this noise pollution source is the study this work is aiming at achieving. The SpectralPlus® audio software was used for quantifying the noise pattern from two locally constructed burr mill grinders – a bigger one (for dried farm produce like cassava, yam and maize) and a smaller one (for things like pepper and tomatoes). The burr millers noise spectrum was flat and with their peaks at about-24.51 dB and -26.06 dB. The peak frequencies for different food materials were 1603 Hz (Maize), 840 Hz (Cassava), 1012 Hz (Yam), 919 Hz (Tomato), 845 Hz (Beans) and 772 Hz (Pepper). The cut-in (when the operators start perceiving sound) and cut-off frequencies (when they stop perceiving sound) averaged between 183.93 Hz (at -4.59 dB) and 364.27 Hz (at -3.80 dB) respectively. Comparing this to the optimum human hearing range of 1 kHz to 4 kHz, and normal human conversation of 60 dB (or approximately -45 dB using relative amplitude scaling) and ambient noise of -27.5 to -26.73 dB due to the burr mills, the operators will have to struggle to hear clearly and shout to be heard because of the noise.

1. INTRODUCTION

In Nigeria, many machines are operated, that are very noisy either by design or due to aging, for example food grinding machine and portable electric generators (Haruna and Agu, 2012). According to USEPA (2013) studies have shown that there are direct links between noise and health problems. Problems related to noise pollution include stress related illnesses, high blood pressure, speech interference, hearing loss, sleep disruption, and loss of productivity (Rabinowitz, 2000; Rosenlund *et al*., 2001; Lusk, 2002; Raul *et al*., 2003; Stansfeld and Matheson, 2003; Matsui *et al*., 2004; McBride, 2004; Goines and Hagler, 2007; Okedere and Elehinafe, 2011; NIDOCD, 2019). Noise-induced hearing loss (NIHL) is the most common and often discussed health effect, but research has shown that exposure to constant or high levels of noise can cause an adverse health effect such as aggression (NPC, 1981; Schnell *et al.*, 2013; USEPA, 2013; Easteal *et al.,* 2014; Ni, *et al.,* 2018). According to Schnell *et al.* (2013), a growing body of literature has been focusing on effect of noise pollution and other environmental factors on stress and health of individuals with many of these researches focusing on their impact on the subjective sense of discomfort. The studies were conducted in indoor micro-environments, work places or on soldiers in extreme outdoor conditions. For example, Clausen *et al.* (1993), Federspiel (2001), Federspiel *et al.* (2002), Toftum (2002), Fang *et al.* (2004), and Mirella *et al.* (2013) conducted their studies indoor while Kirstel-Boneh *et al.* (1995), Rashid and Zimring (2008) conducted their studies at respondent work place while Kjelberg and Landström (1994) as well as Epstein *et al.* (2000) experimented on soldiers in extreme outdoor conditions. Haruna and Agu (2011)'s work on Kaduna Airport noise in Nigeria shows a rather calmer environment when compared to that of a busy airport like Dubai (Balooshi and Ahmad, 2008). Haruna and Agu (2012) also did a simulation work on some old grinder and concluded that running them was a source of discomfort to those in the neighbourhood and often caused quarrels. Vardhan *et al.* (2004) in their work on industrial machineries concluded that there is an increase and stringent regulations are coming into force, limiting the exposure of workers to industrial noise. Industrial noise and its consequences are thus growing in importance to employers, local and central government officials, trade unions, occupational hygienists and physicians and insurers.

Not all mechanical vibrations can be perceived by the hearing mechanism of the human ear. Firstly, the vibrations have to be of a certain magnitude to be audible and secondly, the frequency has to be within certain limits, normally 20 to 20,000 Hz (NPC, 1981). The weakest sound pressure that can be detected by an 'average person' at 1000 Hz is found to be 0.0002 µbar (Gary, 1999; Steven, 2001). On the other hand, the largest sound pressure perceived without pain is of the order of 1,000 µbar. Furthermore, Steven (2001) presented the model of a human ear in his work. The way humans perceive noise within the dB range has been modeled using 'A', 'B' and 'C' weightings and 'D' (Xin, 2013) and is shown in Figure 1. Weighting emphasizes frequencies in the 500-10,000 Hz range, which envelopes the range of greatest sensitivity by the human ear, that is 1 kHz to 4 kHz. The 'A – weighting' correlates well with hearing damage according to Lamancusa (2000), hence it was used in the SpectraPlus® software for this work.

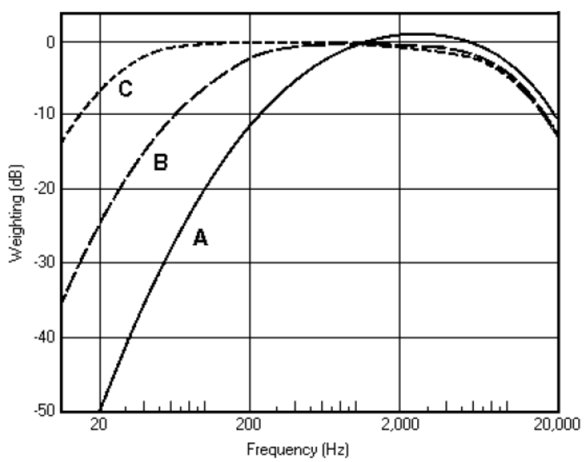

Figure 1: ANSI standard A, B and C weighting curves (Roger, 2001)

As machines are a major source of noise in Nigeria (Haruna and Agu, 2012), it has become increasingly important to evaluate the amount of noise that is being produced by various machines and the components contributing mostly to the noise. This is important not just in the improvement of human life but also in the improvement of machine life and efficiency. For example, a noisy bearing is an indication of an impending failure. It is thus crucial to determine the levels of noise being radiated from machines to be able to adequately proffer means of attenuating these noises.

Furthermore, when measurements are made of the noise produced by a specific machine, the intent of the investigation is often on what changes can be made in its design or in its environment so as to reduce that noise on the people near it. The narrow bandwidth regions (regions within which the noise spectrogram has the greatest complexities of frequencies) must thus be examined. This is where a device capable of splitting the noise generated into its component is required (Erik, 1994; and Lamancusa, 2000).

The aim of this work is to quantify the noise from two types of common food grinding machines, both locally constructed by using Fast Fourier Transform (FFT) analysis software (SpectralPlus® version 5.0). The mills are not commonly used for milling the same type of products; the smaller burr mills are for wet products (Tomato, Beans, Pepper) and the larger burr mills are mostly for dried products (Dry Maize, Cassava and Yam).

2. MATERIALS AND METHODS

2.1. Instrumentation and Equipment

The instruments used for the experiments are, Sound pick up device (AHUJA® AUD-99XLR microphone), Fast Fourier Transform (FFT) analysis software (SpectralPlus® version 5.0). An HP G42 laptop with Realtek high-definition audio mixer with SpectralPlus® version 5.0 installed. The burr mills (Figure 2 and 3) are the noise sources. Both work on the same principle. They consist of two roughened circular grinding plates (Figure 4a) with one stationary and the other rotating. The space between them is adjustable using screw with wheel as shown in Figure 4b. In between them, the materials to be milled are crushed as they pass through them. The bigger grinder (heavy duty grinder) is used for crushing and pulverizing dry and really hard foods like dried yams (*Discorea sp.*) and maize (*Zea Maize*) while the other one is smaller and is used for wet foods like pepper and tomatoes. The two machines were selected to be about the same age of use and everyday use pattern.

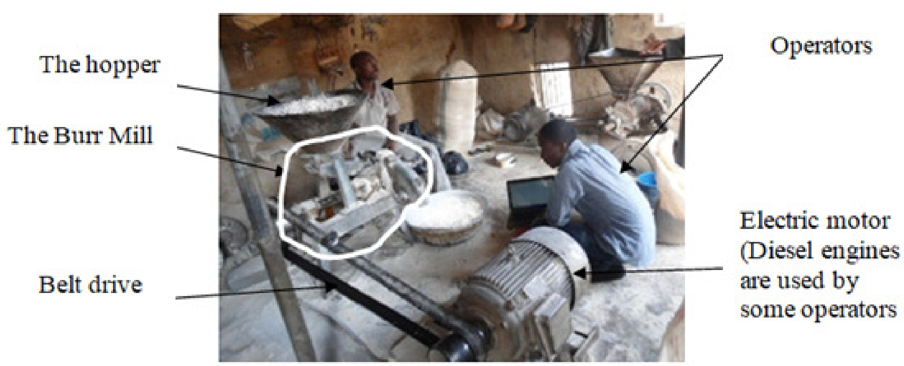

Figure 2: The burr milling machine meant for heavy duty works

a) Petrol engine version b) Electric engine version

Figure 3: Smaller burr milling machine meant for light duty works

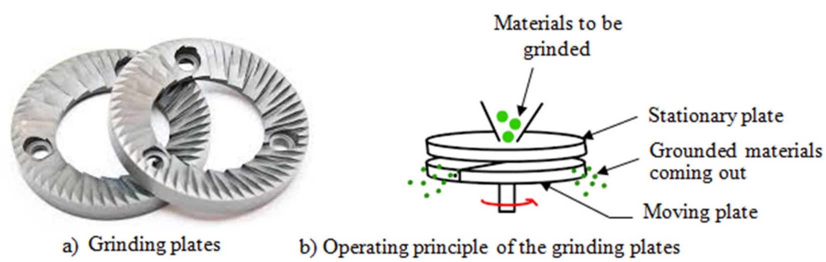

Figure 4: Burr milling machine grinding plates

2.2. Measurement Process

The noise measurements were performed using BS (1987) standard. The standard assumes that noises from machines were obtained under their operating conditions. The microphone orientation was ensured to be within the free sound field (about 1 m from the noise sources). The free sound field is defined by American Standard Acoustical Terminology as a homogenous, isotropic medium free from boundaries. In practice, it is the field within which the effects of boundaries are negligible over the region of interest. Furthermore, an A weighting (Figure 1) was used in the software as it correlates with human hearing damage zone (Agilent 2012; 2013) and is the one recommended for machinery noise measurement by BS (1987) standard. Since the focus is on the damaging effect of the noise generated around the operators, the microphone was placed at their head level and 1 m away in accordance to BS (1987) standard (Figure 5).

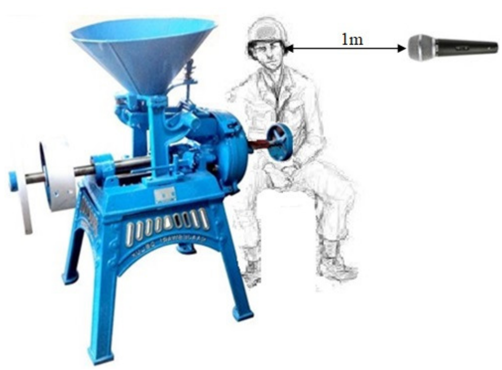

Figure 5: Microphone placements for measuring noise spectrum at grinding machines operators head level

Finally, for testing operator hearing ability, audio generator within the SpectralPlus® was set to generate pure tones with frequency sweep ranging from 5 Hz to 2 kHz with 20,000 msec as frequency sweep interval. The frequency and decibel at which an operator is able to hear the sound (cut-in frequency) and when the operator could not hear again (cut-off frequency) were also while the frequency sweep experiment was on. The calibration of the microphone was done using the SpectralPlus® software utility for microphone calibration. The FFT analysis software eliminates the need for an acoustic calibrator as the calibration can be done directly from the software.

Following the BS (1987) recommendation in the course of the measurements, it was ensured that the ambient sound level was at least 7 dB(A) lower than the sound level produced by each of the machine being tested. Also abiding to the BS (1987) standard (the recommended environmental temperature range of 29 °C and 60 °C), all noise measurements were taken at an average environmental temperature of 34 °C.

3. RESULTS AND DISCUSSION

Table 1 summarize the measured relative amplitude (maximum) and the frequency at which they occur for the big burr milling machine while Table 2 summarize the measured relative amplitude (maximum) and the frequency at which they occur for the small burr milling machine. Table 3 is the cut in frequencies (when the operators began to perceive sound) and cut-off frequency (when they stopped perceiving sound) all at above -30 dB. Comparing the Tables 1 and 2 with Table 3, none of the operator was able to perceive the machines average mid frequencies noise level. For example, in Table 1, dry Maize grinding will cause the big burr mill to generate 1603 Hz mid frequency at -21.16 dB. The first operator will not be able to perceive that sound clearly since his cut-off frequency is 379.52 Hz (-3.84 dB). That bur mill sound has to be amplified for him to hear it, the meaning it that his hearing pattern has become damaged. Normal human beings hear perfectly within the range of 500 – 20000 Hz and converse at 60 dB (approximately -45 dB using relative amplitude scaling). The operator cannot hear what the person (a customer) is saying to them perfectly and easily except customer shouts or the operator shouts. They are psychologically cut-off – that is, they feel the person they are talking with is more composed if he/she is not shouting back while they are rather agitated or rather vexed because of the hearing challenge, hence they can become aggressive in the process.

The results of these experiments are further illustrated in Figures 6 to 12. The vertical scaling unit of the charts is in relative amplitude of the sound measured (in dB) while the horizontal axis for all the charts is frequency (measured in Hz – 0 Hz to 20 kHz) and the scaling is logarithmic. The dB in relative amplitude as used in this work means that 0 dB is equivalent to 90 dB(A) (A weighting) which is the maximum sound power level a worker is allowed to be exposed to continually for 8 hours as agreed internationally by Occupational Safety and Health Administrations (OSHA) (Lamancusa, 2000; Steven, 2001). This OSHA recommendation will cause hearing damage in approximately 25% of the population (Lamancusa, 2000). Figures 6 to 12 illustrate the spectrum of each material being grinded and the type of machine used. Of note is the difference between the wet maize milling sound spectrum (Figure 11) and the dry maize sound spectrum (Figure 10) when using the large burr mill. There is peaking (that is increase in the noise level between 1.5 kHz and 2 kHz for the dry maize while the wet maize does not exhibit this behaviour, possibly because the presence of water dampens the noise. However, the two-burr mill design generally have similar sound spectrum pattern. The difference is the peak frequencies which is different for the materials being grinded. Also, the noise levels of the lighter burr mills are higher than that of the large burr mill due to the material used in constructing its milling chamber (Wei *et al.,* 2019). The heavy burr mill milling chamber is made from cast iron whereas that of the lighter one is made from thin welded steel plates. There is a degree of noise damping with the ones made from cast iron.

The wet materials dampen the noise (as noted in the case of the larger burr mill when milling wet and dry maize (Figure 10 and 11) and the dried products are also expected to increase the noise level. However, the small burr mills are rather louder despite being used for wet food. The thinking is that it may be because the small grinding machines are made from sheet metals while the big ones are made from cast iron. Naturally, the sheet metal will have a reverberating or “drum” effect while the cast iron (which is thicker) will act as a damper for the big ones. In the authors’ undocumented interaction with people who live in the neighbourhood as well as the findings of Haruna and Agu (2012), it is seen that operation of the smaller burr mill is usually characterised by unbearable noise. It was also observed that the burr mill machine operators are generally aggressive and are prone to quarrel with their customers regularly. Furthermore, the results showed that their average cut-in frequency 183.93 Hz (-4.59 dB) and average and cut-off frequency 364.27 Hz (-3.80 dB) range were outside normal human hearing range of 500-20000 Hz and optimum human hearing range of 1 kHz to 4 kHz. Thus, they need loud sound (-4.59 dB for cut-in and -3.80 dB for cut-off) for them to perceive what is being said. It is felt that their continuous exposure to the noise from these machines may be contributing to this aggressive behaviour among other factors. Furthermore, the thinking is that they may be having challenges hearing the conversation from their customers and thus needs to shout at them which makes them seem or act aggressively without provocation.

Table 1: The peak noise level and its frequency for the big burr mill

Experiment	Material being grinded	Relative amplitude (dB)(Average)	Frequency (Hz) (Average)
1	Dry maize	-21.16	1603
2	Wet maize	-32.00	890
3	Cassava	-25.78	840
4	Yam	-25.30	1012
	Average	-26.06	1,086.25

Table 2: The peak noise level and its frequency for the small burr mill

Experiment	Material being grinded	Relative amplitude (Db) (Average)	Frequency (Hz) (Average)
1	Tomato	-25.76	919
2	Beans	-24.50	845
3	Pepper	-23.28	772
	Average	-24.51	845.33

Table 3: Hearing behaviour of the machine operators – consolidated

Operator set	Cut-in frequency	Decibel (Relative amplitude)	Cut-off frequency	Decibel (Relative amplitude)
a	199.18Hz	-4.27dB	379.52Hz	-3.84dB
b	166.88Hz	-5.03dB	349.91Hz	-3.75dB
c	185.72Hz	-4.47dB	363.37Hz	-3.82dB
Average	183.93Hz	-4.59 dB	364.27Hz	-3.80 dB

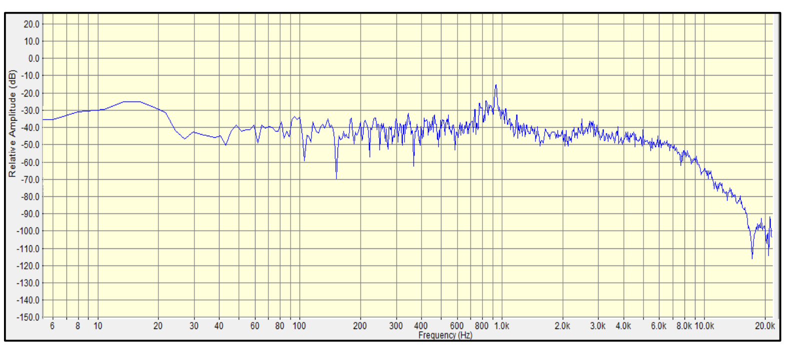

Figure 6: Light burr mill sound spectrum while milling soaked beans

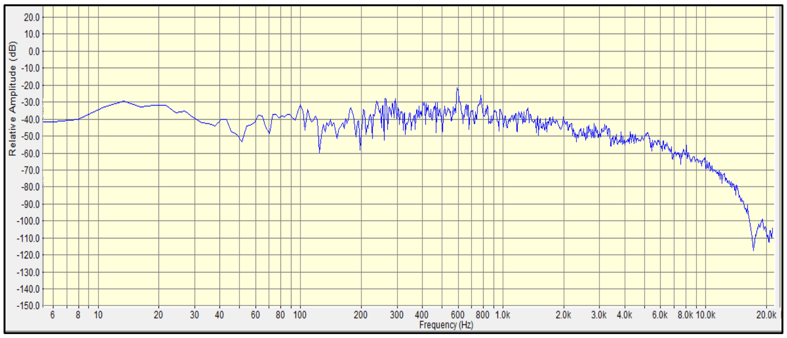

Figure 7: Light burr mill sound spectrum while milling pepper

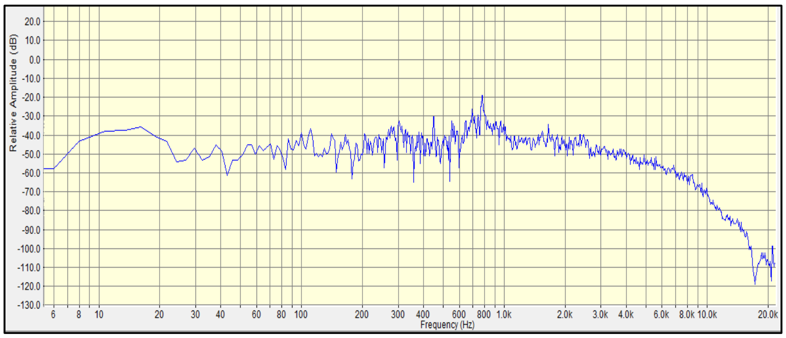

Figure 8: Light burr mill sound spectrum while milling tomato

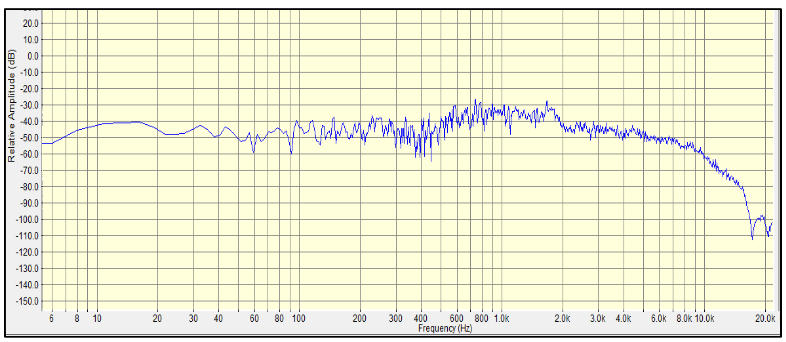

Figure 9: Large burr mill sound spectrum while milling dried cassava

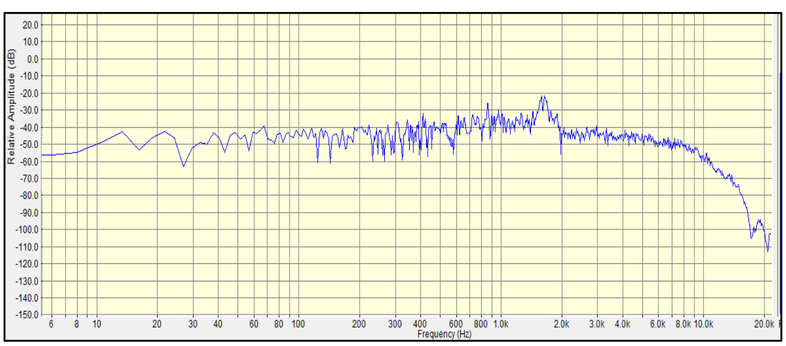

Figure 10: Large burr mill sound spectrum while milling dry maize

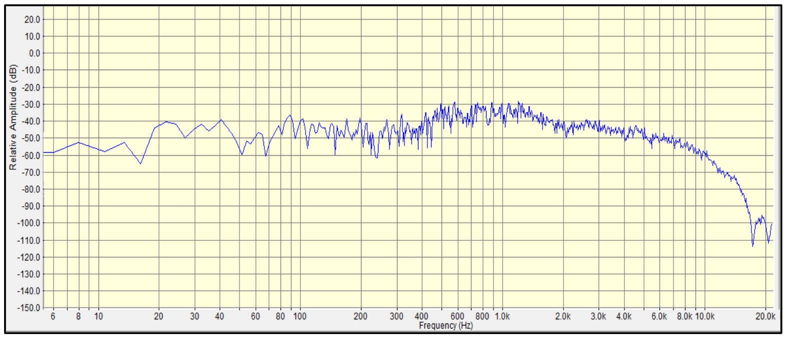

Figure 11: Large burr mill sound spectrum while milling wet maize

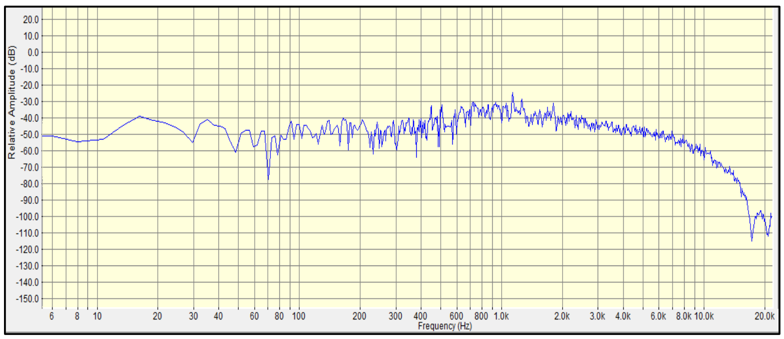

Figure 12: Large burr mill sound spectrum while milling dry yam

4. CONCLUSION

The noise by the burr milling machines were successfully quantified using the Fast Fourier Transform (FFT) analysis software (SpectralPlus® version 5.0). On the average, the smaller burr mill is generally louder than the bigger burr mill, (-24.51 dB and -26.06 dB). The connection between the noise level and aggression seems to be established by the authors' observation of the cut-in and cut-off frequencies which are abnormal for the operators and was also reported by other researchers. However, other factors may also be contributing to this. Thus, there is a need to redesign the burr mills such that the noise pollution from them is reduced.

5. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Agilent (2012). Agilent Spectrum Analysis Basics. Application Note 150. Available online: http://cp.literature.agilent.com/litweb/pdf/5952-0292.pdf.

Agilent (2013). A Refresher Course on Windowing and Measurements. Available online: http://www.home.agilent.com/upload/cmc_upload/All/6C06DATAACQ_WINDOWS.pdf.

Balooshi, A. and Ahmad, M. A. (2008). Assessment of Noise Impact of Air Traffic at Dubai International Airport. Available online: https://core.ac.uk/download/pdf/230623509.pdf

BS (1987). *BS 6805-2:1987, Statistical methods for determining noise emission values of machinery and equipment*. BSI Standard Publication.

Clausen, G., Carrick, L., Fanger, P.O., Kim, S.W., Poulsen, T., Rindel, J.H., (1993). A comparative study of discomfort caused by indoor air pollution, thermal load and noise. *Indoor Air,* 3 (4), p. 255

Easteal, M., Bannister, S., Kang, J., Aletta, F., Lavia, L. and Witchel, H. (2014). Urban Sound Planning in Brighton and Hove. Proceedings of Forum Acusticum, Krakow, Poland, 2014.

Epstein, Y., Heled, Y., Moran, D. and Shapiro, Y. (2000). Prediction of physiological response from mathematical models. *Journal of the Israel Medical Association,* 138 (9), pp. 713-719.

Fang, L., Wyon, D.P., Clausen, G. and Fanger, P.O. (2004). Impact of indoor air temperature and humidity in an office on perceived air quality, SBS symptoms and performance. *Indoor Air,* 14, pp. 74-81.

Federspiel, C.C., (2001). *Cost of responding to complaints.* In: Spengler, J. (Ed.), Indoor Air Quality Handbook. McGraw-Hill, New York, pp. 1278-1297.

Federspiel, C.C., Liu, G., Lahiff, M., Faulkner, D., Dibartolomeo, D.L. and Fisk, W.J. (2002). Worker Performance and Ventilation: Analyses of Individual Data for Call-center Workers. *Proceedings: Indoor Air* 2002, pp. 796-801.

Gary, P. S. (1999). MUS150: Musical Acoustics. Available online: https://ccrma.stanford.edu/CCRMA/Courses/152/SPL.html.

Goines, L. and Hagler, L. (2007) Noise Pollution: A Modern Plague. *Southern Medical Journal*, 100(3), pp. 287-293.

Haruna, A. and Agu, M. N. (2011); Simulation of Airport Noise. A case Study of Kaduna Airport. *International Journal of Environmental Issues*, 7(2), pp. 163-167.

Haruna, A. and Agu, M. N. (2012). Simulation of Levels of Noise Generated by Local Grinding Machines Within the Community (A Case Study of Kaduna Metropolis, Nigeria). *Science and Technology*, 2(6), pp. 146-151.

Schnell, I., Potchter, O., Epstein, Y., Yaakov, Y., Hermesh, H., Brenner, S., & Tirosh, E. (2013). The effects of exposure to environmental factors on Heart Rate Variability: An ecological perspective. *Environmental Pollution*, *183*, pp. 7-13.

Kirstel-Boneh, E., Melamed, S., Manfred, S. and Green, D., (1995). Acute and chronic effects of noise exposure on blood pressure and heart rate among industrial employees: the Cordis study. *Archives of Environmental Health,* 50 (4), p. 245,

Kjelberg, A. and Landström, U. (1994). Noise in the office: part II e the scientific basis (knowledge base) for the guide. *International Journal of Industrial Ergonomics*, 14, pp. 93-118,

Lamancusa, J. S. (2000). Noise Control. Available online: http://pcfarina.eng.unipr.it/Public/Acoustics-Course/Penn-State-Course/1_intro.pdf

Lusk, S. (2002). Preventing Noise-Induced Hearing Loss. *Nursing Clinics of North America*, 37, pp. 257-262

Matsui, T., Stansfeld, S., Haines, M. and Head, J. (2004) Children's Cognition and Aircraft Noise Exposure at Home. *The West London Schools Study. Noise Health*, 7, pp. 49- 57

McBride, D. (2004) Noise-induced Hearing Loss and Hearing Conservation in Mining. *Occupational Medicine*, 54, pp. 290-296.

Mirella, M.M., Hugo Fernandes, S.R., Francisco, J. M. B., Daniela, P. F., Antonio, F. A. N. and Sandro, T. (2013). Noise-Induced Hearing Loss (NIHL): Literature review with a focus on occupational medicine. *International Archives of Otorhinolaryngology*, 17(2), pp. 208–212.

Ni, P. A. N., Anugrah, S.S. and Joko, S. (2018). The Soundscape Assessment of Three Urban Parks In Bandung Based On The Relationship Between Noise Level and Activities In Urban Park. 25th International Congress on Sound and Vibration, 8-12 July 2018.

NIDOCD (2019). Noise-Induced Hearing Loss. National Institute on Deafness and Other Communication Disorders. Available online: https://www.nidcd.nih.gov/health/noise-induced-hearing-loss.

NPC (1981). *Noise Effects Handbook; A Desk Reference to Health and Welfare Effects of Noise*. Available online: http://www.nonoise.org/library/handbook/handbook.htm.

Okedere, O. B. and Elehinafe, F. (2011). Noise pollution implications of base transceiver stations of telecommunication industries in Nigerian. *New York Science Journal*, 4(9), pp. 98-101.

Onuu, M. U. (2007). Level and spectra of Aircraft and People's Reactions in some Nigerian Cities. *Nigeria Journal of Physic*s, 19(2), pp. 5-10.

Rabinowitz, P. (2000) Noise-Induced Hearing Loss. *American Family Physician*. 61, pp. 2749-2756.

Rashid, M. and Zimring, C. (2008). A review of the empirical literature on the relationships between indoor environment and stress in health care and office settings: problems and prospects of sharing evidence. *Environment and Behavior*, 40 (2), pp. 151

Raul, M., Bruce, K., Robert, A. D. and James, C. (2003). Noise-Induced Hearing Loss. *Journal of occupational and Environmental Medicine*, 45 (6), pp. 579-581

Roger C.W. (2001). Noise and Vibration. *Plant Engineer's Handbook,* pp. 707, 709-719

Rosenlund, M., Berglind, N., Jarup, L. and Bluhm, G. (2001) Increased Prevalence of Hypertension in a Population Exposed to Aircraft Noise. *Occupational and Environmental Medicine*, 58(12), pp. 769–773.

Schnell, I., Potchter, O., Epstein, Y., Yaakova, Y., Hermesh, H., Brenner, S. and Tirosh, E. (2013). The effects of exposure to environmental factors on Heart Rate Variability: An ecological perspective. *Environmental Pollution*, pp. 183:7-13

Stansfeld, S. and Matheson, M. (2003). Noise pollution: Non-auditory effects on health. *British Medical Bulletin*, 68(1), pp. 243-257.

Steven W. S. (2001). The Scientist and Engineer's Guide to Digital Signal Processing. Available online: http://www.dspguide.com/pdfbook.htm.

Toftum, J., (2002). Human response to combined indoor environment exposure. *Energy and Buildings*, 34 (6), pp. 601-606.

USEPA (2013). Air Topics. Available online: https://www.epa.gov/environmental-topics/air-topics

Vardhan, H., Rao, Y.V. and Karmakar, N.C. (2004). Noise Analysis of Heavy Earth Moving Machinery Deployed in Opencast Mines and Development of Suitable Maintenance Guidelines for its Attenuation - Part 1. *Noise & Vibration Worldwide,* 35(8), 11-24.

Wei, C., Sheng, H., Hao, C., Tao, H., Xiaowen, W., Ling, L. and Jiwen, P. (2019). Review on Research process of Sound reduction Materials. IOP Conference Series: Materials Science and Engineering 612 (2019) 052062.

Xin, Q. (2013). Noise, vibration, and harshness (NVH) in diesel engine system design. *Diesel Engine System Design*, pp. 759–821.