

Noisiness and Perceived Noise Levels in Some Food Processing Industries in Jos

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Abstract

Measurement of noise sound pressure levels in food processing industries, a social survey to determine the extent to which the workers were disturbed by the noise in the same industries, in Jos, were carried out. In all the industries, only one had equivalent continuous noise level below 85dBA. The results of the physical measurements showed that the noise was predominantly broad-band, continuous and steady state. Noisiness and perceived noise levels were obtained from the results of the physical measurements. The result showed that perceived noise levels were not more than 2dB higher than their corresponding equivalent continuous noise levels implying that the human ear perceives noise (2 dB maximally) higher than that measured by a sound level meter on A-weighting scale. For noise levels at 90dB and above small increase would result to higher noisiness increase. However, noise level and perceived noise level have continuous and steady dependence at all values. The correlation coefficient for noise rating and perceived noise level Υ_1=0.8599, and the correlation coefficient for noise annoyance and perceived noise levels Υ_1=0.8892, both showing strong positive correlations between objective and subjective assessment of noise.

Keywords: Noisiness, perceived noise level, annoyance, noise rating.

1. Introduction

Noise as an environmental pollutant is almost an inescapable by-product of industrial mechanization. Unlike other forms of environmental pollutants, noise does not physically accumulate in the atmosphere (Priest, 1973). Noise is any disturbance that obscures the clarity of a signal. Noise perception is psychological and subjective since it is based on individual consideration and judgment (Stephens and Bates, 1966; Porges, 1977). Due to increased mechanization, industrial noise pollution is also on the increase. Recently noise levels in sundry processing and manufacturing industries in Ilorin metropolis, Nigeria, were assessed and the noise levels in these companies were approximately 90dBA (Oyedipo and Saadu, 2009). Most food and drink industries have processes which emit high noise levels exceeding the 80dBA and 85dBA levels at which employers are required to take action under the control of Noise at work Regulations 2005 (Health and Safety Executive, 2010).

A quantification of noise is difficult because of the subjective considerations involved. This subjective character is reflected in such definitions of noise as “sound undesirable by the recipient”, “stench in the ear” and “sound without value” (priest, 1973). What may be of value to one person may be worthless to another. The sound of an approaching car is priceless to a person who might otherwise have been caught in its path. But it is of negative value to a sleeping person in a nearby house who was awoken by same.

Kryter (1959) developed a relationship between perceived noise level and noisiness as

$$PNdB = 40 + 10\log_2 N \quad (1)$$

Noisiness is the state or quality of being ‘noisy’. Its unit, the noy is the sound pressure level of a 1000Hz tone at 40dB. Perceived noise level is a subjective quantity determined by the response of the human ear. The perceived noise level of a particular noise is the sound pressure level of a band of noise from 910 to 1090Hz that sounds as ‘noisy’ as sound under consideration measured in $PNdB$. To calculate the noisiness and perceived noise level, the maximum SPL in each of the octave band centered at 63, 125, 250, 1000, 2000, 4000 and 8000Hz is obtained. From equal–noisiness contours (Fig. 1) the frequency and SPL in dB are used to find the noisiness from the contours and the noisiness calculated using equation (2).

$$N = N_{max} + 0.3\left(\sum N_i - N_{max}\right) \quad (2)$$

N_{max} is the highest noisiness value

$\sum N_i$ is the sum of the noy values in all octave bands.

Noys may be converted to $PNdB$ using

$$N = 2^{(PNdB-40)/10}$$

$$PNdB = 40 + \frac{100}{3}\log N \qquad (3)$$

The relation in equation (3) can further be simplified as in equation (1), i.e.

$$PNdB = 40 + 10\log_2 N$$

Most efforts to regulate environmental noise for the protection of public health and welfare have relied on social surveys to quantify the effects of noise on people. For example the descriptors recommended in Rosenblith and Stevens (1953) designed to predict whether or not an exposed population would complain or take legal action against a specific noise source was inadequate. This is so because most of the available evidences suggest that using spontaneous complaints as an index of environmental annoyance is unreliable. Swedish, British and American annoyance surveys show that less than 10% of the populations in those countries complain to public authorities (Lindvall and Radford, 1973). As Borsky (1973) pointed out, complaining is a function of many factors including knowing where to complain, believing that the complaint might be effective, confidence in one's ability to deal with authorities, past complaint experience and so on. North American Complainers have been found to differ from non-complainers in education, value of their home and membership in organizations and thus are not representatives of their communities (Guski, 1977). Apart from empirical evidence that complainers differ from non-complaining members of the public, it is theoretically invalid to draw inferences about populations on the basis of non-random, self-selected samples such as those made up of people who complain to public authorities (Babbie, 1973). With increasing problem of environmental noise, emphasis shifted from a prediction of overt response to a prediction of annoyance (Hazard, 1971; Lindvall and Radford, 1973). Implicit in the shift of emphasis was the need that people should be protected from unhealthy levels of noise whether or not they complained. Moreover, and as to be expected, annoyance proved to be a much more sensitive measure of subjective reaction than complaints and has therefore been suggested to be the best summary indicator of the adverse effects of noise (George et al., 1982).

Schultz (1978) suggested that when people are highly annoyed by noise, the effects of non-acoustical variables are reduced, and the correlation between the noise exposure and the expressed subjective reaction is high both for individuals and for groups. In other words, when the noise exposure is felt to be extreme, people have little difficulty in sorting out their feelings about the noise from their other non-acoustical attitudes. However, arbitrariness in counting the percent highly annoyed drew severe criticism and heated debate between Schultz and Kryter (Schultz, 1978; Kryter, 1982a, Schultz, 1982 and Kryter, 1982b).

The equivalent continuous noise level of a time-varying noise L_{eq} is given by Cunniff (1977) as

$$L_{eq} = 10log_{10}(t_1x10^{L_1/10} + t_2x10^{L_2/10} + \ldots\ldots + t_nx10^{L_n/10})/T \qquad (4)$$

where t_i is the time in hours the workers work in a section whose sound level reading is L_i. T is the total time, i.e. Σt_i

2. Materials and Methods

2.1 Physical Measurements

A-weighted Sound Pressure Levels (SPL) measurements and ⅓-octave band spectra of the noise levels at machine operator positions and at the sites of the companies/industries included in this research were done by the use of Brüel

& Kjaer Impulse Precision Sound Level Meter Type 2209 in conjunction with the ⅓-Octave Band Filter set, Type 1616. The Pistonphone Type 4220 which generates 124dB $\pm$0.2dB at a frequency of 250Hz was used to calibrate the sound level meter. These companies/industries, all located within Jos-Bukuru metropolis were identified to use machinery that generated high levels of noise and had granted permission for the research to be carried out in their premises. Some companies/industries declined participation. The companies were coded with arbitrary letters A to D.

In taking a sound level measurement at a location on the company floor, the microphone was placed at a horizontal distance of 1m from the noise sources (corresponding to the average worker position) and at a height of 1.5m (corresponding to the average head position or ear level) of workers. For all measurements, the sound level meter was held steadily as far away from the body as possible and away from any hard reflecting surface or material. With the meter function selector switch on "slow" and the weighting network selector switch on "A" weighting, for readings on the dBA scale, the sound level was read and recorded. Finally a ⅓-octave band filter was coupled to the sound level meter and with the meter deflection damping characteristics on "slow" and frequency weighting selector switch on "linear", the ⅓-octave band sound pressure levels were obtained. Measurements were made between the usual business hours of 8:00 am and 5:00 pm, when the companies/industries were in full operation. Care was taken so that the measurements were made with the minimum interference with normal working patterns as possible and that none of the measurements was influenced by external noise, such as aircraft or road traffic noise. These measurements were repeated on subsequent visits to confirm that the noise environment had remained unchanged.

Sound pressure levels (dB) were converted to noisiness (noy) and subsequently to perceived noise levels ($PNdB$) using the scale developed by Kryter (1959) as shown in figure 1. Using equal noisiness contours, the decibel scale was converted into a series of increments given in noy from the chart at the right of the graph; the noy scale was converted into Perceived Noise Level ($PNdB$) using equation (1)

3. Subjective Assessment

To assess the subjective impact of noise on the workers, a questionnaire was used. While a few respondents completed the questionnaire on their own, in most cases, the researchers asked the respondents questions and entered their responses into the questionnaires. This helped to avoid incomplete responses and non-return of questionnaire, loss of questionnaire, misunderstanding of the questions and other shortcomings on the part of the respondents.

4. Results and Discussion

4.1 Sound Pressure Level (Physical Measurement)

The noise levels obtained in the sections of the mills were very steady and continuous and practically devoid of any impulse or tonal components. The values represent noise levels for given mill locations (sections) since the noise levels for single location were constant.

For a given mill, employees were not confined to only one work station and therefore the time that a typical employee spent at each location within an area was then estimated from data supplied (during interviews) by the foremen and supervisors of the mills. Thus each work station was assigned an equivalent level and an exposure time.

This meant that variations in sound level caused by movement among locations within an area were treated in the same manner as time-varying noise levels at any particular location. During a single 9-hour shift, an employee worked 8 hours, spending the remaining 1 hour time of break in the day in areas where the noise levels were also measured. This was accounted for in the calculations.

Table 1 shows the equivalent continuous noise levels of the mills obtained using equation (4), the noisiness (N) obtained by using the scale of equal noisiness contour as shown in Figure 1 and the perceived noise levels (PNdB) obtained using equation (1) whose results agree with the chart in Figure1.

5. Social Survey

The Questionnaire was administered to assess the social impact of noise present in the mills. Their responses were collated.

As provided for in the questionnaire, respondents had the options of rating the workplace as noisy, quiet, moderately or even declined to comment or were ignorant.

The overall noise rating of workplace was calculated by introducing scale values, x, in the form of numbers to represent the employees' workplace noise rating. The numbers x=4, 3, 2, 1, 0 represent noisy, in between, quiet, don't know and refused respectively and n is the number of responses. The overall workplace noise rating was found to be noisy. Table 2 shows the overall rating of mills noise by respondents.

The overall rating of annoyance was calculated by introducing scale values, x, in the form of numbers to represent the employees' annoyance rating. The numbers x = 4, 3, 2, 1, 0 represent "extremely", "very much", "moderately", "slightly", and "not at all annoyed" respectively and n is the number of responses. Table 3 shows the overall rating of noise annoyance by employees in mills.

To obtain the correlation coefficient for the perceived noise levels and noise rating of the mills, the $PNdB$ values from Table 1 are reproduced in Table 4. The perceived noise level values are the x-variants and noise ratings by employees represented by their corresponding scale values are the y-variants.

Using Pearson's equation for correlation coefficient,

$$\gamma = \frac{\sum XY - \frac{(\sum X)(\sum Y)}{n}}{\sqrt{\left(\sum_X 2 - \frac{(\sum X)^2}{n}\right)\left(\sum_Y 2 - \frac{(\sum Y)^2}{n}\right)}} \quad (5)$$

For the correlation coefficient for perceived noise levels and mill noise rating by employees

$$\gamma_1 = \frac{2940 - \frac{775 \times 33.87}{9}}{\sqrt{\left(67279 - \frac{(775)^2}{9}\right)\left(128.83 - \frac{(33.87)^2}{9}\right)}}$$

$= 0.8599$

This result shows that the perceived noise levels and noise rating of the mills were more than 85% correlated.

The correlation coefficient for the noise annoyance rating and the perceived noise levels was obtained. This was calculated by the use of perceived noise levels (from Table 1) and the average employees' noise annoyance rating (from Table 3) shown in table 5. The perceived noise levels are the x-variants while annoyance rating are the y-variants.

The correlation coefficient from Pearson's equation

$$\gamma = \frac{\sum XY - \frac{(\sum X)(\sum Y)}{n}}{\sqrt{\left(\sum_X 2 - \frac{(\sum X)^2}{n}\right)\left(\sum_Y 2 - \frac{(\sum Y)^2}{n}\right)}}$$ is

$$\gamma_2 = \frac{1141.57 - \frac{(775)(12.94)}{9}}{\sqrt{\left(67279 - \frac{(775)^2}{9}\right)\left(20.34 - \frac{(12.94)^2}{9}\right)}}$$

$= 0.8892$

This means that the correlation between perceived noise levels and annoyance is about 89%

6. Conclusion and Recommendation

The physical measurements in this work showed the noise which was predominantly broad-band, continuous and steady-state exceeded the 80dBA equivalent continuous noise levels recommended by U.S EPA to protect the median worker from incurring any NIPTS in three of the four industries. The noisiness which is a function of noise levels showed that at 90dBA and above, small increase in noise level resulted to very high increase in nosiness (noys). The calculated values of the perceived noise levels were not more than 2dB higher than their corresponding equivalent continuous noise levels. The result supported the fact that the A-weighting is close to the sensation of the human ear since the perceived noise level ($PNdB$) is the noise level value as perceived by the human ear. The correlation between perceived noise levels and annoyance is stronger than that between perceived noise level and noise rating showing that though noise rating and annoyance are both subjective, annoyance is more strongly related to perceived noise levels. From this work the following recommendations are made:

An investigation into the effects of spectral content and duration on perceived noise levels which would give the Effective Perceived Noise Levels EPNL should be made.

An investigation into the effects of background noise on Perceived Noisiness should be carried out

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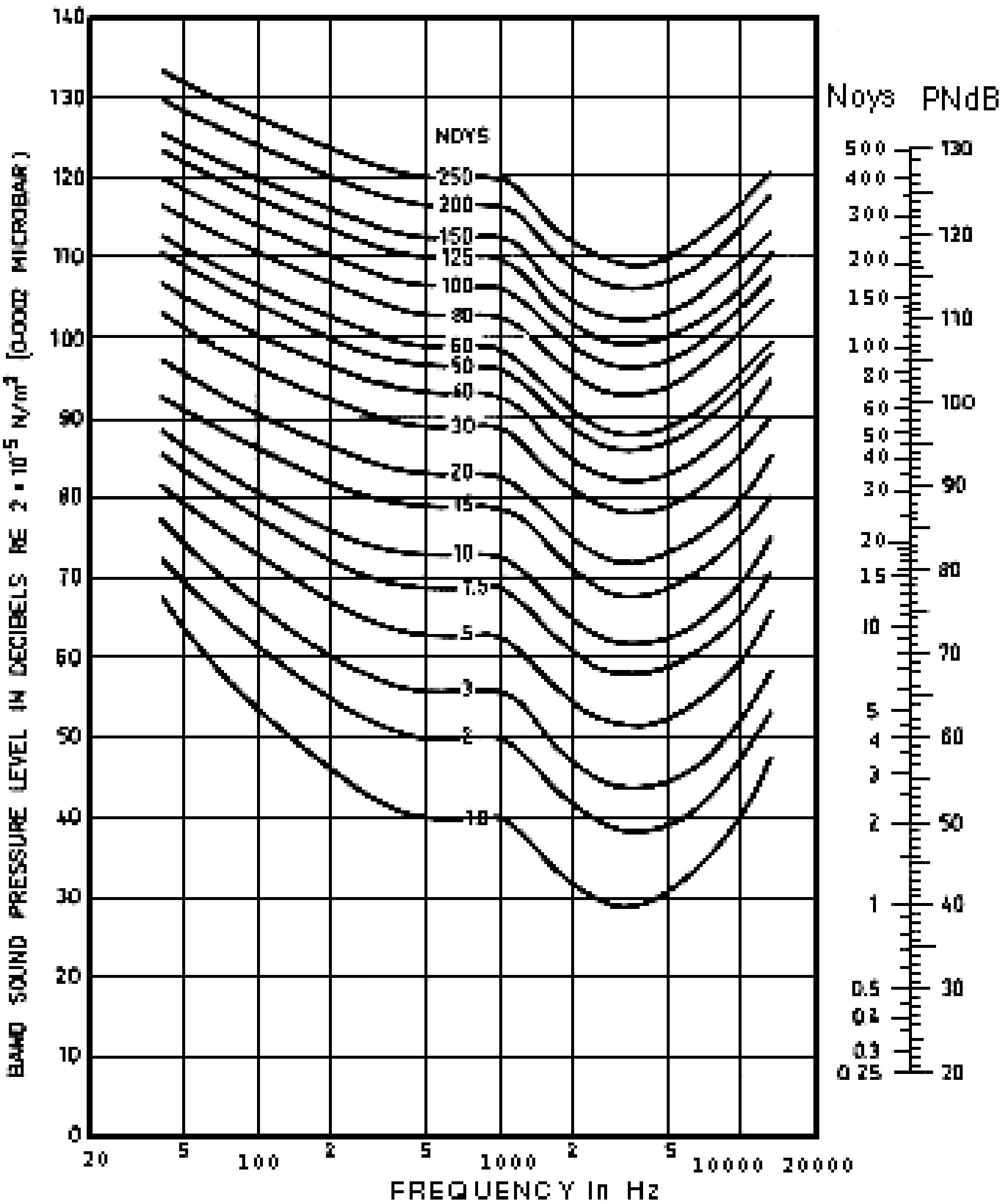

Fig 1: Scale and Chart for Noisiness and Perceived Noise Levels (kryter, 1959).

Table 1: Noise Levels, Noisiness and Perceived Noise Levels of the Mills

INDUSTRY	MILLS	dBA	noy	PNdB
A	A_1	92	40	93
	A_2	87	30	89
	A_3	90	34	91
B	B_1	85	25	87
	B_2	89	32	91
C	C_1	89	32	91
	C_2	86	27	88
D	D_1	75	13	77
	D_2	67	07	68

Table 2: Overall Rating of Mill Noise

		Number of Responses in each Workplace Noise Rating Workplace Noise Rating							
Company	Mill	Noisy (4)	Moderate (3)	Quiet (2)	Don't Know (1)	Refused (0)	Response Per Zone	Weighted Rating. $\sum nx$	Ave. value $\sum(nx/n)$
A	A_1	57	0	1	0	0	58	230	3.97
	A_2	53	0	1	0	0	54	214	3.96
	A_3	53	2	1	0	0	56	220	3.93
B	B_1	62	6	1	0	0	69	268	3.88
	B_2	76	8	0	0	0	84	328	3.90
C	C_1	51	6	0	0	0	57	222	3.89
	C_2	25	3	0	0	0	28	109	3.89
D	D_1	53	8	2	0	0	63	238	3.78
	D_2	2	12	4	0	0	18	48	2.67

Table 3: Overall Rating of Noise Annoyance

		Respondents' Noise Annoyance Rating								
COMP-ANY	MILL	Extre-mely (4)	Very Much (3)	Mode-rately (2)	Slightly (1)	Not at all bothered (0)	Total	Weighted Rating. Σ(nx)	Average Response Rating. Σ(nx/n)	L_A dBA
A	A_1	6	8	28	4	12	58	108	1.86	92
	A_2	2	9	10	10	23	54	65	1.20	87
	A_3	9	7	13	2	25	56	85	1.52	90
B	B_1	6	8	23	20	12	69	114	1.65	85
	B_2	12	5	28	23	16	84	142	1.69	89
C	C_1	5	9	19	13	11	57	98	1.72	89
	C_2	2	6	6	9	5	28	47	1.68	86
D	D_1	2	7	13	26	15	63	81	1.29	75
	D_2	0	0	0	6	12	18	6	0.33	67

Table 4: Variants for Calculating Correlation Coefficient for Perceived Noise Levels and Noise Rating by Employees

INDUS.	MILL	X_i	Y_i	X^2_i	Y^2_i	X_iY_i
A	A_1	93	3.97	8649	15.76	369.21
	A_2	89	3.96	7921	15.68	352.44
	A_3	91	3.93	8281	15.45	357.63
B	B_1	87	3.88	7569	15.05	337.56
	B_2	91	3.90	8281	15.21	354.90
C	C_1	91	3.89	8281	15.13	353.99
	C_2	88	3.89	7744	15.13	342.32
D	D_1	77	3.78	5929	14.29	291.06
	D_2	68	2.67	4624	7.13	181.56
	Total	775	33.87	67279	128.83	2940.67

Table 5: Variants for Calculating Correlation Coefficient for Perceived Noise Levels and Employees' Annoyance

INDUSTRY	MILL	X_i	Y_i	X^2_i	Y^2_i	X_iY_i
A	A_1	93	1.86	8649	3.46	172.81
	A_2	89	1.20	7921	1.44	106.80
	A_3	91	1.52	8281	2.31	138.32
B	B_1	87	1.65	7569	2.72	143.55
	B_2	91	1.69	8281	2.86	153.79
C	C_1	91	1.72	8281	2.96	156.52
	C_2	88	1.68	7744	2.82	147.84
D	D_1	77	1.29	5929	1.66	99.33
	D_2	68	0.33	4624	0.11	22.44
	Total	775	12.94	67279	20.34	1141.57