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FURTHER INVESTIGATION ON NOISE DISTRIBUTION FUNCTION

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The results of a recent noise survey by the author show the existence of a well defined distribution function for the noise level fluctuations inside air conditioned landscaped offices in Hong Kong. In the present study, further noise measurements are carried out inside canteens where the equivalent sound pressure level can be as high as 82 dBA and with higher degree of intermittency. The previous determined distribution function is also found to be applicable in these acoustical environments.

1. INTRODUCTION

The results of a large-scale acoustical environment survey in air conditioned landscaped office buildings in Hong Kong by Tang [1] suggest that the A-weighted percentile levels L_Ns vary approximately linearly with the A-weighted equivalent sound pressure level L_{eq}. Tang [1] also showed under this condition that the cumulative distribution C of the noise level can be represented by a log-tanh function of the form

$$\log_e C = k_4 \{\tanh [e^{k_2} (\log_e I + k_3)^{k_1}] - 1\} \quad (1)$$

within engineering tolerance and ks are real numbers determined by L_{eq}. The argument of the function I denotes intensity ratio with the A-weighted sound intensity as the reference. The purpose of using A-weighted sound intensity is that the A-weighted L_{eq} has been shown by Tang [2] to be the best noise index to correlate with human auditory sensation in office environment among the commonly used indices. The basic function of (1) is to give an estimate of the noise level statistics by using a known or specified L_{eq} and it will be beneficial to the evaluation of an acoustical environment and the setup of specifications for environmental assessment. Further details of (1) can be found in Tang [1]. However, the L_{eq} range of Tang [1] is limited to from 45 to 65 dBA as it is unusual to obtain higher L_{eq} in office environment. Also, similar to the case of the Weibull distribution [3], the physical meanings of the ks in (1) have not been determined [1]. In the present study, the use of (1) in higher L_{eq} condition is examined.

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2. EXPERIMENTAL SETUP

The experiments were carried out in three different canteens inside the Hong Kong Polytechnic University from 8:00 to about 20:00 on weekdays. The major source of sound was human speech while the noise generated by crashing utensils and moving chairs came second. The sound pressure levels were recorded every second using a Brüel & Kjær 2236B precision sound level meter operated in the 'fast' response mode. It was held securely on a tripod and the locations of sound measurements were far away from walls and nearly in the middle of each canteen. L_{eq} and L_Ns within 5 min intervals were calculated from the recorded sound pressure level time series using a FORTRAN computer programme. The 5 min interval for the calculation of L_{eq} for an unsteady noise situation is recommended by Baldwin [4]. The coefficients of the regression lines discussed later also depend on this time interval and it is found that their variations are negligible when such interval is longer than 4 min. Obviously, the length of this interval cannot be too long; otherwise the unsteady noise level fluctuations cannot be reasonably revealed by the computed data. A 5 min time interval appears to be a suitable choice. At least two sets of measurements were conducted in each canteen.

3. RESULTS AND DISCUSSIONS

The noise level inside a canteen varies from time to time due to occupancy level and human activities. Figure 1 shows some examples of the time variations of L_{eq} and the noise climate (L_{10}–L_{90}) recorded in the present study. The noise is high at the beginning of the lunch hours (12:00–14:00). This may be due to a relatively

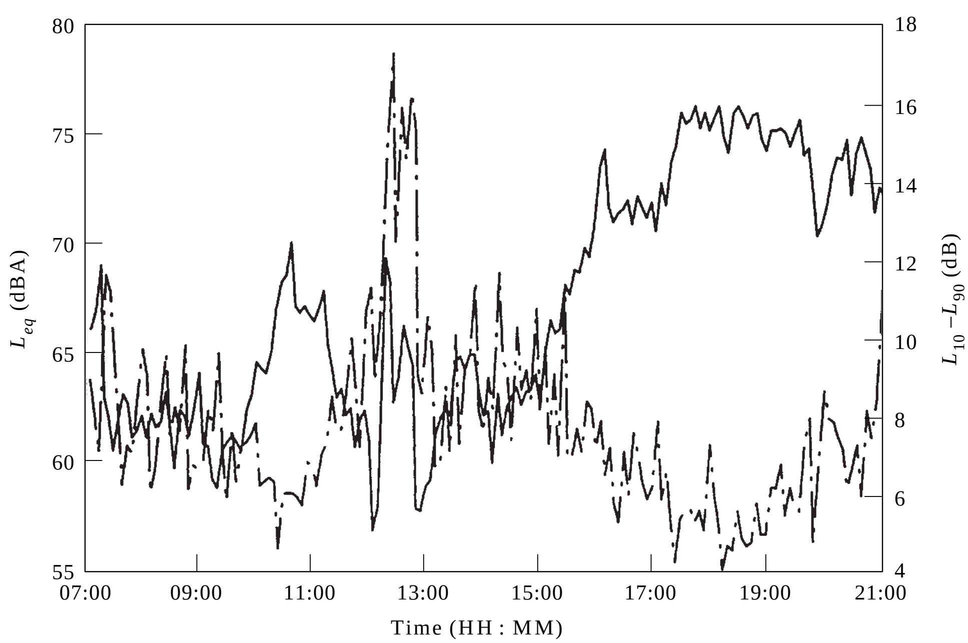

Figure 1. Time variations of L_{eq} and noise climate in a canteen. ——, L_{eq}; — · —, noise climate.

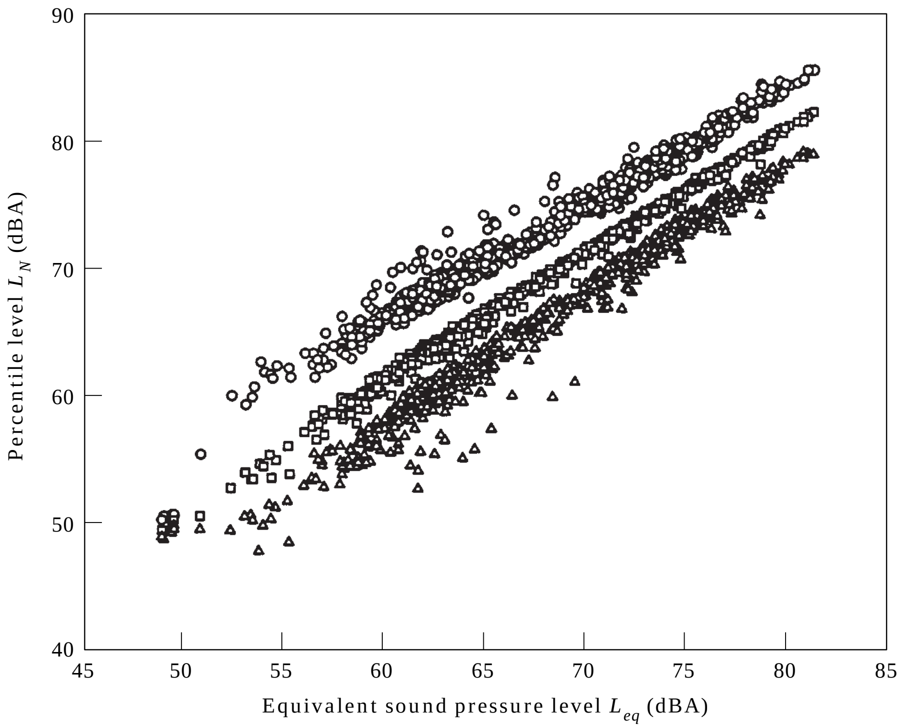

Figure 2. Examples of linear relationships between L_Ns and L_{eq}. ○, L_{10}; □, L_{50}; △, L_{90}.

larger flow rate of occupants and the rapid utensil collection which created intermittent noise. Higher sound pressure levels were recorded during breakfast (09:00–11:00) and dinner (17:00–20:00) hours while the noise climates within these periods were low. One of the plausible reasons for this phenomenon is that the people were more relaxed during breakfast and dinner hours so that they talked more loudly and a more steady acoustical situation was achieved. The high sound pressure levels recorded between 20:00–21:00 were due to the cleaning up of the canteen and were not included in the foregoing discussions. It can be observed that the range of L_{eq} in the present study is from 50 dBA to about 82 dBA while 45 dBA $< L_{eq} <$ 65 dBA in Tang [1]. Also, the noise in the present study is more unsteady than that in Tang [1] especially during the lunch hours. The meridian of the noise climate distribution in the office noise survey of Tang [2] is only about 8 dB.

The existence of linear relationships between L_Ns and L_{eq} is crucial for (1) to be applicable as shown in Tang [1]. Such relationships for $5 \leqslant N \leqslant 95$ are also observed in the present L_{eq} range and some examples of them are illustrated in Figure 2. The L_Ns presented are overall averaged values within 0·1 dB L_{eq} intervals. A relatively more significant data scattering is observed for L_{90}. This is probably due to the occasional short duration quiet periods during the measurement so that L_{eq} is determined by the higher noise level generation inside the canteens, resulting in relatively higher L_{eq} with a low L_{90}. The associated noise climate is high. An

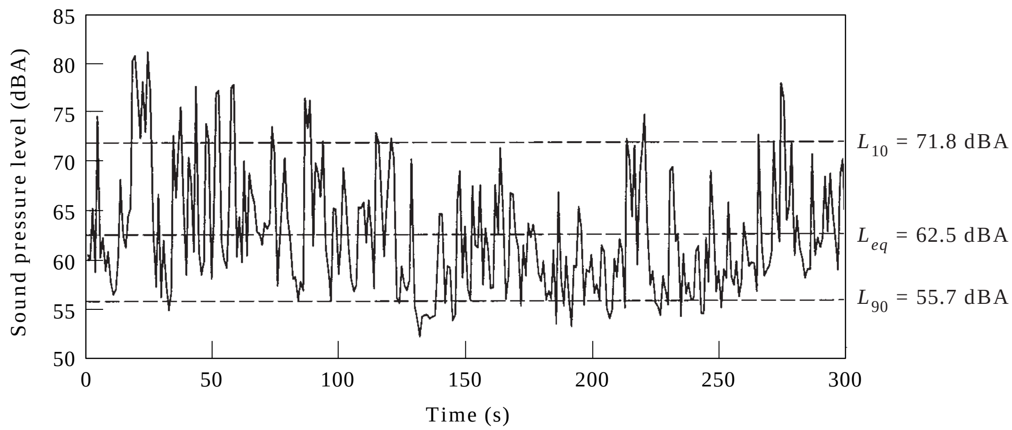

Figure 3. Example of noise level fluctuations.

example of this phenomenon is illustrated in Figure 3. An extreme case of it has been observed for traffic noise by Burgess [5].

Table 1 summarizes the linear relationships, the corresponding correlation coefficients R^2 and the uncertainty range of the linear approximation e as in Tang [1]. The coefficients of the linear relationships shown in Table 1 differ significantly from those given in Tang [1]. Further investigation involving a thorough comparison between these two sets of results are required in order to explain this observation. Following the procedure of Tang [1], the cumulative distribution and the probability density function at a particular L_{eq} can be estimated.

Figure 4(a) and 4(b) show the comparison between the measured sound pressure level probability density function and that predicted using (1) for $L_{eq} = 65$ and 73 dBA respectively. The collapse of data for the cumulative distribution function is even more impressive (not shown here). The choice of L_{eq} for comparison in Figure 4 is purely arbitrary. While good agreement between measurement and

TABLE 1

Summary of linear relationships between L_Ns and L_{eq}

N	Linear relationship	R^2	e (dB)
5	$L_5 = 0{\cdot}890L_{eq} + 14{\cdot}321$	0·951	$\pm 0{\cdot}13$
10	$L_{10} = 0{\cdot}925L_{eq} + 10{\cdot}542$	0·974	$\pm 0{\cdot}07$
20	$L_{20} = 0{\cdot}963L_{eq} + 6{\cdot}396$	0·990	$\pm 0{\cdot}03$
30	$L_{30} = 0{\cdot}985L_{eq} + 3{\cdot}872$	0·995	$\pm 0{\cdot}02$
40	$L_{40} = 1{\cdot}003L_{eq} + 1{\cdot}851$	0·996	$\pm 0{\cdot}01$
50	$L_{50} = 1{\cdot}017L_{eq} + 0{\cdot}146$	0·994	$\pm 0{\cdot}02$
60	$L_{60} = 1{\cdot}030L_{eq} - 1{\cdot}401$	0·992	$\pm 0{\cdot}03$
70	$L_{70} = 1{\cdot}041L_{eq} - 2{\cdot}889$	0·988	$\pm 0{\cdot}04$
80	$L_{80} = 1{\cdot}051L_{eq} - 4{\cdot}417$	0·983	$\pm 0{\cdot}06$
90	$L_{90} = 1{\cdot}062L_{eq} - 6{\cdot}248$	0·975	$\pm 0{\cdot}09$
95	$L_{95} = 1{\cdot}070L_{eq} - 7{\cdot}696$	0·965	$\pm 0{\cdot}13$

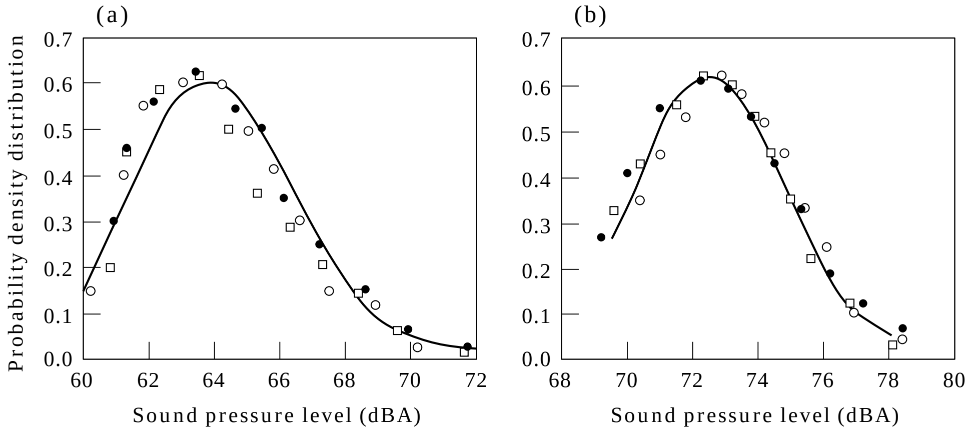

Figure 4. Comparison of probability density functions. (a) $L_{eq} = 65$ dBA; (b) $L_{eq} = 73$ dBA. ——, Present distribution (1); ○, canteen A; □, canteen B; ●, canteen C.

prediction is observed for $L_{eq} = 73$ dBA, less satisfactory performance of (1) is found for $L_{eq} = 64$ dBA. The reason for this is not precisely known. However, it should be noted that the accuracy of the prediction depends on how well the regression lines shown in Table 1 can represent the data. It can be observed from Table 1 that the error e increases with N and therefore, one can expect less satisfactory performance of (1) for predicting L_N when N is large. In the probability density distribution, this corresponds to the region of lower sound pressure levels, explaining the discrepancy at sound pressure level less than 64 dBA shown in Figure 4(a). It should also be noted that the scattering of data is far less serious at higher L_{eq} (Figure 2), suggesting (1) performs better at higher L_{eq} conditions provided that sufficient amount of data is available. In general, agreement of the kind shown in Figure 4 can be observed over the whole L_{eq} range in the present study though poorer agreement close to the lower and upper limits of L_{eq} due to insufficient samples can be anticipated. This suggests that the function proposed by Tang [1] can be applied in the range 45 dBA $< L_{eq} <$ 82 dBA.

It has been discussed by Tang [1] that the function (1) represents a skewed distribution. The data on Safeer *et al*. [6] obtained near an airport show a high skewness while the results of Burgess [5] show the existence of linear relationships between L_{eq} and L_{10} for flow road traffic in Australia. The results of a more recent study of Chakrabarty *et al*. [7] on noise at road conjunctions also suggest, though in an implicit way, the latter linear relationship between L_{eq} and L_{10}. These seem to suggest that the function (1) may also be applicable to the study of other community noise. An extensive investigation related to outdoor situations is currently undertaken by the authors.

4. CONCLUSIONS

Sound pressure level measurements were carried out in three canteens where the sound pressure levels as well as the percentile levels varied substantially with time. The 5-min equivalent sound pressure level could be as high as 82 dBA. The log-tanh distribution function proposed by Tang [1] was found to be able to represent the present experimentally determined sound level cumulative and probability density distributions within engineering tolerance, thus extending its applicability. However, the present distribution function is still not yet fully developed. The physical meanings of the constants involved and its relationships with other commonly used distribution functions in statistics are left to further investigations.

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