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A. GARCIA and L.J. FAUS

Laboratory of Acoustics, Applied Physics Department, University of Valencia, Valencia, Spain

ABSTRACT. Environmental noise measurements have been carried out in different cities and locations of Spain. The noise levels have been continuously sampled over 24 hour periods using a noise level analyzer. The data contained in this paper represent a total of 4200 measurement hours. All this information has been used to investigate the time patterns of the noise levels under different conditions and to study the correlations between several noise descriptors in urban areas.

1. INTRODUCTION

Community noise surveys have been carried out in numerous countries over the past thirty years (1). The type of noise measurements have been dependent on the purposes for which the surveys have been conducted: evaluation of noise exposure on urban populations, comparison of current noise levels with values specified in regulations, assessment of the impact of noise from planned developments, etc.

In general, the noise levels measured in urban areas show a wide temporal and geographical variation. The distribution of instantaneous noise levels measured in a given location can be explained as the sum of two different components: a distant process with a relatively low mean value and variance, which comprises an accumulation of many noise sources and it is represented by the lower percentiles, and a local process with a higher mean value and variance, related with a smaller number of noise sources relatively close to the measuring point, and responsible for the upper percentiles of the distribution. The relative contribution of both processes to the observed noise levels is different during night and day periods.

The best way to deal in a consistent manner with the temporal noise fluctuations is to make a statistical analysis of a time record of the noise. Ideally, such analysis would be made in bands of frequency and would distinguish between day and night, weekdays and weekends, winter and summer, etc. In practice, however, some concessions to economy are always necessary. The first simplification is usually consider only the A-weighted sound levels, a step for which there is ample justification. Subsequent economy steps may involve a drastic reduction of the observation time periods (often restricted to diurnal periods) or the use of measurement equipment less complicated that statistical analysis gear (such as integrating sound level meters). Obviously, the information obtained with these strategies is usually valid for general purpose studies (for instance, to measure the noise map of a city), but it is not sufficient for more specialized objectives (for...
instance, to provide a complete understanding of the existing sound environment in urban areas and to establish criteria for the preparation of realistic noise regulations).

In many respects, the increase of noise pollution in Spain during the last decades has followed a similar trend to other technologically advanced countries. The noise measurements carried out in Madrid, Barcelona and Valencia have revealed that the diurnal equivalent sound levels in these cities are rather high, with mean values about 70 dBA (2)(3)(4). On the other hand, the measurements carried out in some Spanish medium-sized cities have revealed that their noise climates are not significantly different to the bigest cities (5)(6).

As a further contribution to a better knowledge of this problem, the variation of noise levels over 24 hour periods has been measured in a number of selected locations in several Spanish cities. Most of measuring points are dominated by road traffic noise. This survey covers a total of 4200 hours of noise level recordings (175 complete days) carried out from 1980 to 1989. In this paper we present the first results of the global analysis of all data obtained in these measurements.

NOISE MEASUREMENTS

Noise levels have been measured continuously over 24 hour periods in 50 different selected locations of seven Spanish cities: Valencia (population 710,000), Pamplona (185,000), Alcoy (66,000), Gandia (51,000), Playa de Gandia (40,000), Burjasot (36,000) and Pobla de Vallbona (8,000).

All measurements have been carried out using a 1/2 inch condenser microphone (BK4165), a noise level analyzer (BK4426) and an alphanumeric printer (BEC2312). For practical reasons, the microphone was not mounted at street level, but in a balcony of a dwelling (generally, the homes of relatives or friends). In all cases, the instantaneous sound levels were sampled each 0.1 seconds, resulting in a total count of 36,000 samples per hour. The hourly values of $L_1$, $L_{10}$, $L_{50}$, $L_{90}$, $L_{99}$ and $L_{eq}$ have been obtained through 24 hour periods. In some cases, these continuous measurements covered several consecutive days in order to study the day effects.

Our present files include a total of 25,200 data (six different hourly noise parameters for 175 complete days of measurements). All this information has been processed in a Tandon PCA computer using a specific software developed in our laboratory to obtain the statistical distributions of the different noise parameters, the variation of noise levels with sampling time and sampling days, and the correlations between percentiles and equivalent sound level values.

RESULTS AND CONCLUSIONS

The values of hourly equivalent sound level found out in all measurements (4,200 data) show a wide dispersion, ranging from 27 dBA to 84 dBA, with a mean value of 63.0 dBA and a standard deviation of 7.4 dBA. Only 12% of these data are lower than 55 dBA. The mean values of the different percentile noise levels range from 50.1 dBA ($L_{99}$) to 73.3 dBA ($L_1$).

In general, the time patterns of the noise levels are similar in all cases. The time variation of the diurnal noise levels (from 7.00 to 22.00 hours) is insignificant, specially in the high traffic volume locations (in some urban roads of Valencia, the traffic density is above 70,000-80,000 vehicles per day). The lowest values of the noise levels are usually found at night hours (from 22.00 to 7.00 hours). The noise levels measured in weekdays show a rapid increase from 6.00 to 9.00 hours, reaching a maxima at 14.00 hours, followed by a small decrease at 16.00-17.00 hours, a new maxima at 20.00 hours and a regular decrease period to reach the lowest values at 5.00 hours. These results are slightly different for sundays; in this case, for example, after reaching the lowest value at 7.00 hours, the noise levels increase slowly up to 13.00.
The above trends are consistent with that found in other environmental noise measurements carried out in Spain (2-6) and other Mediterranean countries (7)(8), but they can show some minor differences with the observations made at other locations due to the differences in activity and rest hours. On the basis of these differences, the length of day and night periods (and the definition of noise descriptors such as Ldn) should be carefully specified in the corresponding noise regulations.

The values of Leq (24 hr) in all measurements (175 data) range from 40 dBA to 76 dBA, with a mean value of 63.3 dBA and a standard deviation of 5.7 dBA. The values of diurnal Leq (7-22 hr) range from 45 to 79 dBA, with a mean value of 65.1 dBA and a standard deviation of 5.9 dBA. The values of nocturnal Leq (22-7 hr) range from 33 to 74 dBA, with a mean value of 60.6 dBA and a standard deviation of 5.5 dBA.

As the main noise source in all urban areas, the traffic density is the prevailing factor of measured noise levels. However, the analysis of our results shows clearly that the urbanistic structure of the cities (through features such as building density, existence of open spaces, etc.) affects also to their acoustic environment.

The instantaneous noise levels measured in urban areas varies appreciably with time. In locations exposed to heavy and steady traffic the distributions are approximately gaussian; to explain the observed distributions under other conditions (such as quiet residential areas, urban parks, etc.) many other distributions have been used (rectangular, skewed, etc.) (9).

The analysis of the 4,200 hourly data obtained in our measurements, under a wide variety of experimental conditions, has shown that most of noise level distributions are heavily skewed toward the lower level values. However, the asymmetrical character of the distributions decreases when the mean noise level increases and for Leq>70 dBA the observed distributions are approximately normal.

The precise determination of noise level distributions and percentile noise level values Lx is usually based in the use of quite sophisticated and expensive instruments (tape recorders, statistical analyzers, etc.). The use of modern integrating sound level meters gives only the values of Leq for a given time period. Therefore, it is interesting to investigate the Lx-Leq relationship in order to get some relevant information on the statistical distribution of instantaneous sound levels under the different experimental conditions that are usually found in urban areas.

The analysis of all information collected in our measurements (4,200 data) has given the following regression line equations:

\[
\begin{align*}
L1 &= 0.965 \text{ Leq} + 11.5 ; \quad r = 0.959 , \quad d = 2.12 \\
L10 &= 1.031 \text{ Leq} + 0.6 ; \quad r = 0.980 , \quad d = 1.56 \\
L50 &= 1.087 \text{ Leq} - 9.9 ; \quad r = 0.924 , \quad d = 3.33 \\
L90 &= 1.028 \text{ Leq} - 11.5 ; \quad r = 0.851 , \quad d = 4.68 \\
L99 &= 0.957 \text{ Leq} - 10.2 ; \quad r = 0.804 , \quad d = 5.22 
\end{align*}
\]

All these expressions are given in dBA. The best correlation coefficients r and the most accurate estimations (lowest standard deviations d) correspond to L1 and L10 equations and the worse to L90 and L99 equations. This result can be expected since the background noise levels (L90 and L99) observed in absence of nearby noise sources are predominantly influenced by the general setup of a given location, while L1, L10 and Leq values depend upon the specific noise sources truly existing in its immediate vicinity. The values predicted with the above equations are comparable to those obtained with the expressions deduced from other urban noise surveys (10-13).

We have not found any significant differences among the regression equations obtained for the different cities covered in our survey. Therefore, it should conclude that the above equations have a general validity for any prediction of correlations between noise level parameters in urban areas.
The analysis of the regression equations calculated in an hourly basis proves that the correlation coefficients between $L_{10}$ and $Leq$ do not show any significant variation through 24 hours of day (from 0.95 to 0.99); the corresponding equation parameters and standard deviations show only minor changes through the 24 hour period. However, the correlation coefficients between $L_{90}$ and $Leq$ range from 0.65 during the night up to 0.90 at day; these results coincide with those found in an investigation carried out some years ago in England (14). In this last case, the equation parameters show a quite regular variation through the 24 hours of day; the standard deviations range from 2.5 dBA during the evening hours up to 6.0 dBA at 4.00-6.00 hours. Thus the equivalent sound level $Leq$ is an excellent predictor of $L_{10}$ at any time, but it is a rather poor predictor of $L_{90}$, specially during night hours.

A tentative extrapolation of the results obtained in this investigation would allow suggest that in order to reduce the economic cost of general purpose noise surveys in most of Spanish urban areas or other of similar characteristics (related, for example, with the measurement of the diurnal noise map of a city), the complete sampling schedules can be substituted by simple short time measurement techniques using an appropriate noise descriptor ($Leq$), without produce a serious loss of any relevant information. In general, the use of the equations given in this paper (or similar) can afford a sufficient basis to predict the noise level distributions observed in the most usual conditions and thus prescribe reliable noise regulations.

REFERENCES