Are urban noise pollution levels decreasing? (L)

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The majority of acoustic impact studies developed over the last 50 years have used a similar acoustic parameter (L_{eq}, L_{dn}) but the noise mapping methodology has been very uneven. The selection of the measurement points, the measurement periods, or the evaluation indices have not followed a unique criterion. Therefore, it is not possible to compare the sound pollution levels between different cities from those studies, at least in a rigorous sense. Even more, different studies carried out in the same city by different researchers during different years and using different methodologies are not conclusive whether the acoustic pollution increases or decreases. The present paper shows results, with statistical significance, about the evolution of the acoustic pollution obtained for two Spanish cities, Pamplona and Madrid. In both cases, it can be concluded that noise pollution decreases over time ($P < 0.01$).
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I. INTRODUCTION

In science, not all questions are valid. Only questions which are set out in well defined terms and whose answers can be verified quantitatively are deemed appropriate. In order to be able to give a rigorous answer to questions such as "Is city A noisier than city B?" or "Has noise pollution fallen in city A over the last few years?," it is necessary to have an objective evaluation parameter for noise pollution in a city, in addition to a methodology for evaluating it. The majority of acoustic impact studies developed over the last 50 years have used a similar acoustic parameter ($L_{Aeq,T}$), which is related to the acoustic energy during the evaluation period T, typically day L_d, evening L_e, and night L_n periods as well as the combined parameter L_{den} or L_{dn},[1] but the noise mapping methodology has been very uneven. This work analyses the main results obtained when producing noise maps for Pamplona and the measurement records from the environmental monitoring network set up by Madrid City Council, both cases involving Spanish cities. In the case of Pamplona, the corresponding noise maps were made in 1987–1988, 1997–1998, and 2007–2008. In the case of Madrid, the measurement period is from 1999 to 2003, inclusive.

Pamplona is a city with approximately 200 000 inhabitants in the north of Spain. Three noise maps were made for the city in 1987–1988, 1997–1998,[2] and 2007–2008. In all three cases, a total of 162 measuring stations were used, located in the nodes of a cross-linked $220 \times 220\ m^2$, covering the whole consolidated urban area. The measurement station selection can therefore be considered as random. The noise pollution level was characterized by the daytime L_{Aeq} parameter, meaning the equivalent sound level to the time period between 8 a.m. and 10 p.m. All measurements were taken at street level using type I sound level meters during working days (from Monday to Friday) in favorable atmospheric conditions. The measurement stations were assigned to the district of the city where they were located. The most important aspect to highlight is that the methodology used to make these three noise maps (measurement stations, duration, and length of the measurements, parameters measured, etc.) were exactly the same in all three cases.

The Madrid City Council Environmental Department for noise control installed remote control measurement stations in 1998 throughout the city's urban area. Each of them recorded the hourly equivalent sound levels, $L_{Aeq,h}$. Twenty stations continually recorded sound levels over 5 complete years, from 1999 to 2003, inclusive. In total, 876, 480 measurements were recorded for the $L_{Aeq,1h}$ parameter. All commonly established parameters for evaluating noise pollution[3] could be obtained for this work: L_d, L_e, L_n, and L_{den}.

II. RESULTS

Figure 1(A) shows the average noise pollution levels in each district for the three measurement campaigns, as well as the average value of the city's noise pollution. The values indicated for each district correspond to the energy average from the values obtained in all the stations belonging to the district in question. The decrease in noise pollution observed in the district 9, mainly due to the implementation of pedestrian areas, is particularly remarkable

Figure 1(B) shows the evolution of the results for the different parameters (average value of the 20 stations, averaged in terms of energy) from 1999 to 2003.

III. DISCUSSION

As we can see in Fig. 1, a decreasing tendency in noise pollution can be perceived. We should now focus on whether this tendency is significant or not. This should be resolved using the appropriate statistical test. When the data are normal, analysis methods are more efficient than methods based on rank tests. In the case of Pamplona, the measuring stations covered the whole consolidated urban area in detail and their selection was random. The distribution could therefore be considered as normal. However, for the case of Madrid, the data were obtained from fixed measuring stations set up by the City Council without random criteria over a cross-

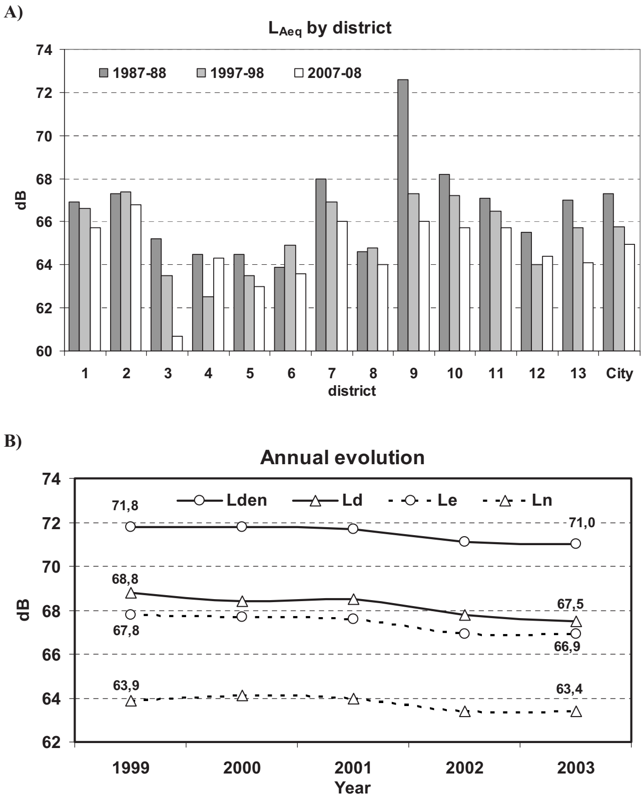

FIG. 1. (A) Noise pollution levels by district and for the whole city of Pamplona (Spain). (B) Annual evolution of the L_d, L_e, L_n, and L_{den} parameters in the city of Madrid (Spain).

linked area. On the other hand, these results are completely solid given that they represent exactly the noise pollution for each measuring station.

The methods based on ranks require less strict assumptions about the population distributions and they are almost as efficient as their normal equivalents when the data follow normal distribution, and they are more efficient when the data do not follow normal distribution. Taking the random block model,

$$Y_{ij} = \mu + \tau_i + \gamma_i + \varepsilon_{ij} \quad (i = 1, \ldots, k; \; j = 1, \ldots, b)$$

where k is the number of populations, b is the number of blocks, μ is the total average, τ_i is the effect due to the population, and γ_j is the effect due to the blocks and ε_{ij} are the random errors.

Tables I and II show the results for the two cities. In the case of Madrid, each value represents the exact noise pollution $-L_{\mathrm{Aeq,24h}}$ averaged annually—in each measurement station. In the case of Pamplona, each value represents the daytime noise pollution on workdays $-L_{\mathrm{Aeq,8-22h}}$ averaged annually—in each district of the city.

In our case, $k=20$ stations and $b=5$ years (Madrid) and $k=13$ districts and $b=3$ decades (Pamplona). To evaluate population differences in the model, the most appropriate ranks-based test (similar to the F-test for normal populations) is the Friedman test. The hypotheses to test are that not all the population effects, τ_I, are null. This means that there is a significant drop in the total noise pollution in both cities. The chi-squared values (from Tables I and II) are 18.27 for four degrees of freedom (Madrid) and 10.54 for two degree of freedom (Pamplona). In both cases, we can conclude that noise pollution decreases over time ($P<0.01$). A decrease in the percentage of people exposed to noise has been also observed in a 1 decade noise climate research.[4]

We must finally remember that the dB measurement is relative to a logarithmic scale. It is more intuitive to assess the reduction in terms of acoustic energy existing in the environment. From this point of view, noise pollution dropped by 17% from 1999 to 2003 in Madrid and by 41% from 1998 to 2008 in Pamplona.

TABLE I. Evolution of noise over time ($L_{\mathrm{Aeq,24h}}$ parameter) in Madrid, Spain.

Madrid, Spain. $L_{\mathrm{Aeq,24h}}$					
			Year		
Station	1999	2000	2001	2002	2003
1	70.3	70.3	70.4	70.3	70.0
2	69.9	69.7	69.5	69.3	69.9
3	66.6	66.8	68.3	67.9	66.3
4	63.0	63.1	63.2	63.2	62.6
5	73.4	73.2	72.7	72.6	73.0
6	67.9	67.3	70.5	66.9	66.9
7	66.8	67.1	67.4	67.5	66.9
8	67.7	67.2	67.2	67.1	67.0
9	71.2	70.6	70.8	70.9	70.8
10	68.0	67.3	66.8	65.8	66.3
11	63.8	62.5	61.6	61.9	62.1
12	70.4	69.3	69.3	68.8	69.4
13	71.2	70.8	70.3	69.7	69.7
14	61.8	63.5	63.6	62.4	62.7
15	64.5	65.2	63.9	63.8	63.7
16	65.1	65.0	65.5	64.6	64.5
17	70.2	70.3	70.2	69.6	68.6
18	69.6	67.6	66.7	66.4	65.8
19	63.6	63.7	64.1	63.9	64.1
20	69.8	70.7	71.1	69.8	69.1

TABLE II. Evolution of noise over time ($L_{\mathrm{Aeq,8-22h}}$ parameter) in Pamplona, Spain.

Pamplona, Spain $L_{\mathrm{Aeq,8-22h}}$			
		Year	
District	1987–1988	1997–1998	2007–2008
1	66.9	66.6	65.8
2	67.3	67.4	66.9
3	65.2	63.5	60.8
4	64.5	62.5	64.4
5	64.5	63.5	63.1
6	63.9	64.9	63.7
7	68	66.9	66.1
8	64.6	64.8	64.1
9	72.6	67.3	66.1
10	68.2	67.2	65.8
11	67.1	66.5	65.8
12	65.5	64	64.5
13	67	65.7	64.2

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