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ANALYSIS AND EVALUATION OF ENVIRONMENTAL NOISE CONDITIONS IN TWO DIFFERENT AREAS IN MEXICO CITY

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Abstract
Mexico City, part of one of the world's most crowded metropolitan areas with a population estimated at approximately 19 million, has major problems of noise pollution. However, existing data on these problems is unfortunately limited. An urban noise survey carried out in two different areas in Mexico City is presented. Two sites limited by different street typologies were chosen: site *A*, with an area of approximately 176 hectares, is located in the northern part of the city's centre; site *B* comprises an area of about 440 hectares in the south of the city. Both places have their own identities, which are shown through their buildings and open public spaces of significant cultural importance. The sites were chosen because they have large volumes of road traffic, and open public spaces with intense human activities. The main objectives of this study has been: 1) to carry out measurements to evaluate urban noise levels from road traffic and leisure activities in open public spaces; 2) to determine if these levels exceed recommended values; and, 3) to compare noise levels of two different places in Mexico City. Measurement of main indexes for noise pollution (L_{Aeq}, L_{10}, L_{50}, L_{90}) and data from traffic flow and composition were acquired in randomly selected sites along streets and inside squares. The results have revealed that: a) environmental noise levels due to road traffic are significantly higher than the guideline values suggested by the World Health Organization and the Organization for Economic Cooperation and Development to protect public health and welfare; b) average sound levels correlated with traffic flow conditions, coincide with those of other authors; and c) environmental noise conditions in the two areas show a certain degree of spatial and temporal variation resulting primarily from the traffic flow and the multiple human activities.

1. INTRODUCTION

The Federal District, Capital of Mexico is located at the geographical centre of the country, together with the municipalities of neighbouring states, form one of the largest metropolitan areas of the world known as the "Area Metropolitana del Valle de Mexico". It registered a population of approximately 19 million inhabitants in 2005; 8.7 million corresponded to the Federal District [1]. This area has the highest human concentration of the country, and is the most important centre of governmental, industrial, commercial, financial, and educational activities of Mexico.

Mexico City has an urban and architectural heritage in many of their neighbourhoods, where cultural and social activities of relevant importance have prevailed. However, the open public space in several sites has been degraded due to environmental, visual, and noise pollution.

During the last years an incipient interest has been observed by public authorities and citizens to reduce these problems. The development of tourist, cultural, and leisure activities has been promoted through a general plan that includes aspects such as land uses, transportation, and environment [2]. Although, it has tried to give an integral solution to the problem of pollution, urban noise has not been considered a priority problem.

Although, relevant discussions of Mexico City's noise problem started at national and international forums in the seventies, [3], scientific work and the development of standards against noise have been scarce and limited [4,5].

The objective of the present investigation is the characterization of the sound environment in two traditional zones in Mexico City, which have in common large traffic flows and intense human activities in open public places. One of the purposes has also been to gather scientific data to be used as source of information for urban projects regarding environmental quality of open public spaces in Mexico City. The present study is part of a Ph.D. research in the field of urbanism made by Ms. German and directed by Mr. Greene.

2. STUDIED AREAS

2.1 Localization

Noise measurements were carried out in two traditional sites of Mexico City (Figure 1), hereafter identified as zones *A* and *B*. The former, with a surface of approximately 176 hectares, is located in the northern part of the city centre. Zone *B* includes an area of nearly 440 hectares in the south of the city. Both of them have similar land use areas, with residential spaces and commercial establishments along their perimeters and predominantly residential uses in the interior.

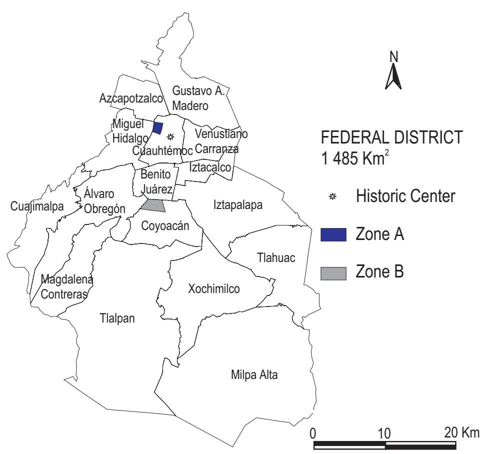

Figure 1. Localization of the studied zones in the map of the Federal District.

Main avenues delimit both zones; secondary and local streets predominate in their interiors. The avenue that limit the west of zone *A* and the north of zone *B* are part of the same freeway that surrounds the central area of Mexico City. Each studied site has an open public space with important vegetation areas, located approximately in the centre of each zone. In site *A*, there is a main plaza of about 26,000 square meters; in a similar way, there are two adjacent plazas in site *B*, divided by a secondary street, with a total surface of 26,700 square meters. These plazas constitute the most important urban elements for gathering in each zone. They are the places where social, cultural, musical, commercial, and leisure activities are carried out.

2.2 Noise Sources

The noise sources considered in this work are those that most affect the users of the public spaces, the pedestrians. In the case of streets, the survey was focused on traffic noise; for the plazas, attention was paid to noise generated by leisure activities.

Although traffic noise has not been recognized as a major problem in Mexico, the World Health Organization [6] and several published papers [7,8] have suggested that environmental noise pollution caused by this source is a significant problem in developing countries.

In Mexico City, the quality of open public spaces has been degraded, mainly in streets, by the increase of the number of vehicles and the expansion of the street network. In 2006 the total number of registered vehicles was slightly higher than 3 million, 68% more than in 1980. Regarding the street network, the extension is larger than 10 thousand kilometres in the city, from which 9% corresponds to primary avenues and 91% to secondary streets [9].

In the open public spaces for gathering of Mexico City, noise pollution is associated with large social concentration due to urban leisure. During weekends, these spaces have large human activities of cultural, economic, and recreational order often accompanied with music and dancing, which in some cases creates a very lively soundscape, but in others it becomes a noise problem that prevents vulnerable people from enjoying those activities.

3. METHODOLOGY

For each zone, the measurement of noise conditions was carried out in the following places: a) all the primary avenues (five in zone *A* and four in zone *B*); b) in secondary streets chosen according to its use and its importance of communication between the centre of the zone with the exterior (four streets in zone *A* and five streets in zone *B*); and c), the interior of the main plazas (Figure 2).

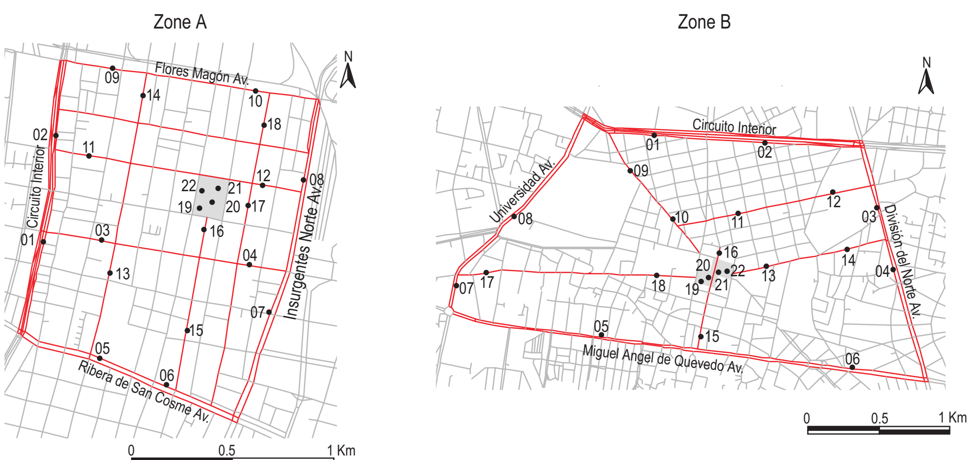

Figure 2. Maps of the studied zones and localization of the measurement points.

In each of the selected avenues and streets, two measurement points were selected at random (Figure 2). The distribution of these points was the following: The points with numbers 1 to 10, corresponding to zone *A* in the map of Figure 2, were situated in main avenues, and the points with numbers 11 to 18 were in secondary streets. Similarly, in zone *B*, the points with numbers 1 to 8 were in main avenues, and points identified by the numbers 9 to 18 correspond to positions in secondary streets.

Even if this sampling point selection method could lead to an overestimation of the environmental noise (being the intrinsic risk of choosing the most crowded sites), it offers the advantage of providing a preliminary characterization of the studied zone, which considerably reduces time and cost [10]. Within the plazas, the measurement points (corresponding to the number 19-22 in each zone) were placed in representative sites of the most crowded or the most transited zones by the pedestrians.

The survey was carried out during February and March of 2007; in avenues and streets between Mondays and Thursdays from 9 AM to 4 PM, and in the plazas on Sundays from 12 noon to 5 PM. The periods of time were chosen because they are representative of the time during the day in which there is the largest number of pedestrians in the sites of study. The work was carried out following the Standards ASTM E 1779-96a (R 2004), E 1503-05 and E1686-03 [11-13]. The noise levels were measured with an integrating sound level meter placed 1.2 m from the floor, 1.5 m farther away from any façades and acoustically reflective surface whose presence was not common in the site. For each point, the duration of a measurement was 10 minutes in each hour of the total measurement period during the day. Values of the equivalent sound pressure levels were registered each second, and the main noise descriptors for each ten-minute measurement, L_{eq}, L_{max}, L_{min}, L_{10}, L_{50}, and L_{90}, were obtained directly from the sound level meter. The traffic flow was also quantified during the measurements for each point. It should be mentioned that the survey was carried out under favourable meteorological conditions.

For the data analysis, the noise levels recommended by the World Heath Organization and the Organization for Economic Cooperation and Development to protect people from the effect of annoyance [6,14], corresponding to 55 dBA and 65 dBA respectively, were taken as a reference.

4. RESULTS AND DISCUSSION

4.1 Characteristics of Traffic Flow

Figure 3 shows, for each measurement point, the traffic flows, expressed as the number of vehicles per hour (veh/h), in the two studied zones. The traffic flow consisted of heavy vehicles, light vehicles, and motorcycles.

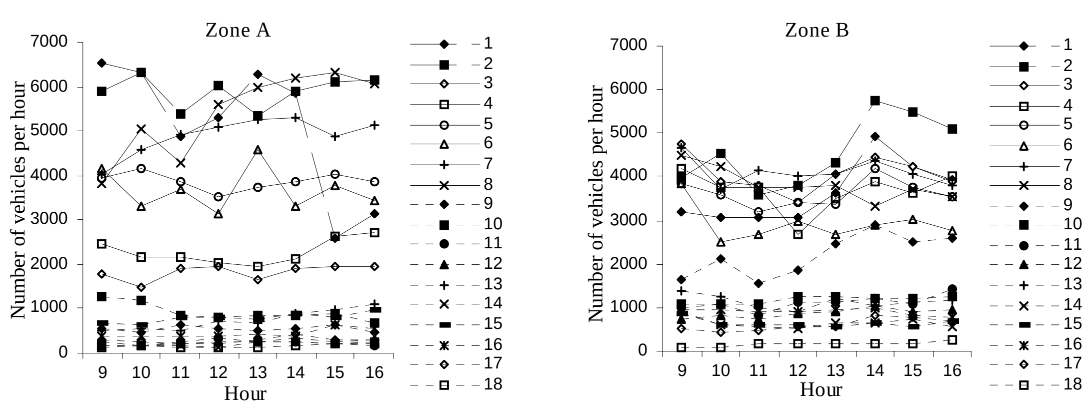

Figure 3.Volume of traffic per hour on points of the surveys, located in avenues & streets of the studied zones.

The average values of the number of light and heavy vehicles per hour in main avenues were 3172 and 220 respectively for zone *A* and 3569 and 179 respectively for zone *B*. In secondary streets, the corresponding average values of the traffic flows were 335 and 22 respectively for zone *A*, and 876 and 56 respectively for zone *B*. As can be seen, the average number of light and heavy vehicles per hour for zone *A* is very similar to the corresponding average for zone *B*; however, in the secondary streets, the traffic flows were approximately 2.5 times higher in zone *B* with respect to zone *A*.

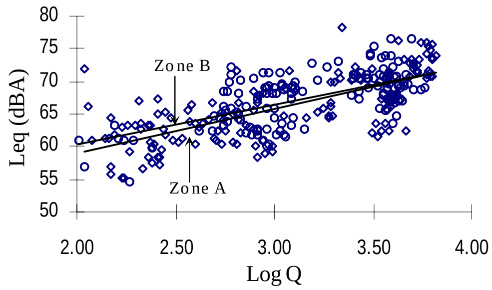

Figure 4. Relation between the L_{eq} and the logarithm of the traffic flow (Q) in the two zones of the survey.

The relations between the equivalent sound pressure levels for the measurement period of 10 minutes and the logarithm (base 10) of the traffic flow for each of the two zones are shown in Figure 4. The obtained correlation coefficients (r) are 0.73 for zone *A* and 0.62 for zone *B*, with $p<0.05$ for both zones. Based on the sample evidence, we conclude that the linear relation between the L_{eq} and the logarithm of the traffic flow is significant for both zones despite the fact that the coefficient of correlation is weak. The equations of the fitted lines are $L_{eq} = 6.8 \text{ LogQ} + 45.4$ for zone *A* and $L_{eq} = 6.1 \text{ Log Q} + 48.2$ for zone *B*. These results are coherent with others reported in the literature [15].

4.2 Noise Levels

4.2.1 Distribution of noise levels

The acoustic differences between the two studied zones can be observed in Figure 5, where we report the percentage of the distribution of the L_{eq} values from the samples registered each second in main avenues, secondary streets, and plazas. For main avenues of both zones, the distribution is almost symmetrical; the modal interval is 65-70 dBA with 27% of the samples for zone *A* and 35% for zone *B*. The other intervals with significant sample percentages are similar between the two zones; 24% for 60-65 dBA, 22% for 70-75 dBA, and 13% for 60-65 dBA for zone *A*; and 23%, 22% y 11% correspondingly for zone *B*. In less of 1% of the measurements in both zones, the L_{eq} values surpass the 80 dBA. It can be assumed that the similitude in these results is due to the fact that the number of vehicles that transit along the main roads is similar in both zones.

In the case of the secondary streets, the distribution in one zone is different from the distribution in the other. In zone *A* the distribution is positively skewed, the major percentage of samples is found in the interval of 50-55 dBA with the 44%; for the interval of 55-70 dBA, 53% of the samples are distributed in descendent form; only 3% of the samples are between the interval of 70-85 dBA. In zone *B* the distribution is symmetrical; the modal interval is 60-65 dBA with 26% of the samples. The remaining 74% is distributed, almost in equal parts, towards the sides of the modal interval. The data show that zone *A* is less noisy than zone *B* in their secondary streets; this can be attributed to the fact that the number of vehicles that travel along the interior streets is 2.5 times larger in zone *B* than in zone *A*.

The distribution of samples in the public spaces is skewed, positively in zone *A* and negatively in zone *B*. The modal interval is 60-65 dBA for the former and 70-75 dBA for the latter, with 48% and 42% of the samples respectively. The distribution of zone *A* has 6% of the samples with levels higher than 75 dBA, while in the distribution of zone *B* the value is 23%. Similarly to the secondary streets, the open public space for gathering is less noisy in zone *A* than in zone *B*.

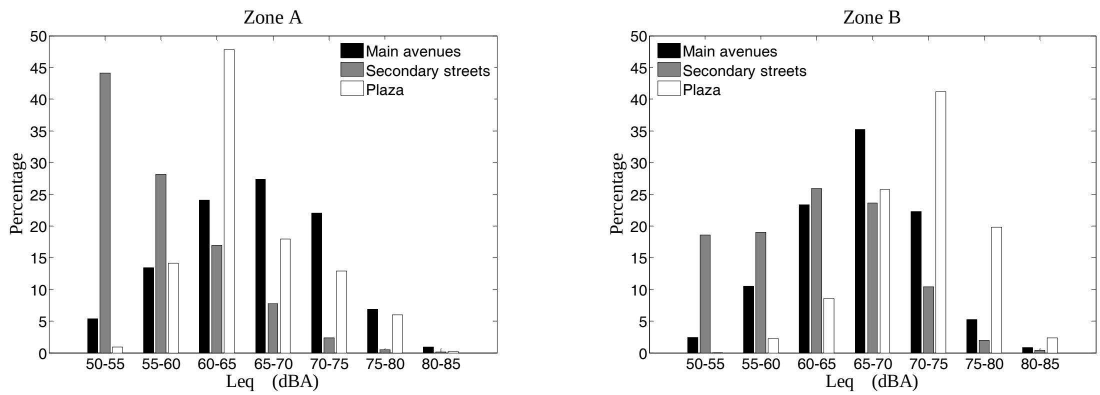

Figure 5. Distribution of L_{eq} values measured in the studied sites.

4.2.2 Noise levels time variation

For avenues, the averages of the L_{eq} values corresponding to each hour are similar between the results of zone *A* and zone *B*. The values of the eight hours of the measurement period are in the interval of 70.0-72.6 dBA in zone *A*, and between 69.6-72.0 dBA in zone *B*. For secondary streets, the L_{eq} values vary more in zone *A* than in zone *B*; in the former la values are found between 61.0-65.8 dBA, and for the later the values are in the interval of 66.8-68.3 dBA.

The largest temporal variation of the L_{eq} appeared in the plazas. At 12:00 noon and 3 PM, which correspond to the time when people start to gather in the sites and the approximate lunch time respectively, the lowest sound levels were registered. The values were 63.6 dBA at 12:00 and 67.5 dBA at 15:00 in zone *A*, and 68.6 dBA and 73.9 dBA correspondingly in zone *B*. After lunch time an increase in the noise level was again observed, 71.5 dBA at 16:00 in zone *A* and 75.6 dBA at 17:00 in zone *B*.

4.2.3 Noise levels spatial variation

The values L_{eq}, L_{max}, L_{min}, L_{10}, L_{50}, and L_{90}, corresponding to each measurement point of both zones are shown in Figure 6. One can observe that the L_{eq} value of 55 dBA recommended for a day time by the World Health Organization is exceeded in all the points of both zones. The L_{eq} is higher than 65 dBA, the value recommended by the Organization for Economic Cooperation and Development, in 13 points of zone *A* and in 18 points of zone *B*. Most of the points where the L_{eq} values were lower than 65 dBA are located in secondary streets. The average of the L_{eq} values among points 1 and 2 in both zones (four points) can be compared with the results obtained in the city of Beijing, China [16] due to the fact that the measurements were carried out in avenues with analogous conditions (a ten lane freeway) and during similar periods of time. In Beijing, the L_{eq} was equal to 73.8 dBA, approximately one dBA higher than the value registered in Mexico City, which was 76.2 dBA.

The average value of the L_{eq} and the standard deviation of the measurements carried out in avenues, secondary streets, and plazas of both zones are shown in Table 1. The average value of the L_{eq} was calculated taken into account all the measurements made in the corresponding site. The average value of the L_{eq} corresponding to avenues is similar in both zones. For secondary streets, the values is almost 5 dBA higher in zone *B*, which can be explained by the fact that the traffic flow in this zone is 2.5 times larger than in zone *A*. It should be emphasized that the highest noise levels were registered in one of the plazas, which means that the social concentrations are causing more noise than the vehicles.

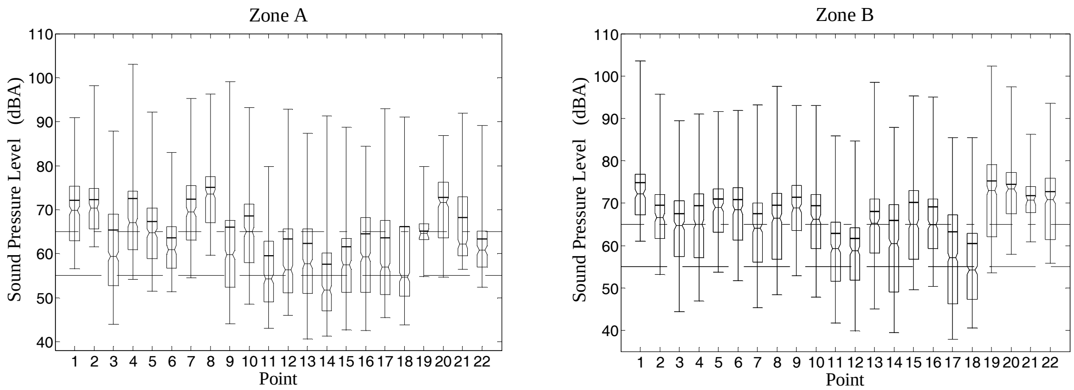

Figure 6. Values of noise descriptors during the measurement period of a day in the in the different sampling points. The horizontal heavy line indicates the L_{eq} value. From top to bottom, the fine horizontal lines correspond to the values of L_{max}, L_{10}, L_{50}, L_{90}, and L_{min} respectively. Also shown are the L_{eq} values recommended by the World Health Organization (---) and the Organization for Economic Cooperation and Development (-··-·-).

Table 1. Average and standard deviation of the L_{eq} values measured in the different kinds of sites in the two studied zones.

	L_{eq}		S.D.	
Zone	*A*	*B*	*A*	*B*
Avenues	70.9	70.7	4.1	2.8
Secondary streets	63.0	67.6	3.2	4.0
Plazas	68.9	73.7	4.5	3.3
Average over avenues and secondary streets	68.5	69.4	5.2	3.9

Finally, the noise levels registered in the study described here are compared with a survey carried out in zone *B* in 1985 and with studies in other cities in the world. In Alicante, Spain [17], and Valdivia, Chile [7], noise measurements were carried out during day time, which did not include the hours of maximum traffic flows (similar situation to the present study). In Alicante, the L_{eq} was equal to 67.8 dBA (in 1992). In Valdivia, the L_{eq} was 68.0 dBA. Both studies presented slightly lower values than the ones obtained in Mexico City. The following five surveys were conducted during periods that included maximum traffic flows. For the city of Badajoz, Spain [15], and Nablus, Palestine [18] the reported values of L_{eq} were 67.8 dBA and 68.0 dBA respectively. They are slightly lower than the case reported here. Examples of cities where the noise levels are higher than the ones of Mexico City are Messina, Italia [10], Curitiba, Brazil (residential zone) [8], and several cities of Nigeria [19], with L_{eq} values equal to 71.6 dBA, 75.6 dBA, and 84.6 dBA respectively. The survey carried out in Mexico City in 1985 [4] reported, for the period from 13:00 to 22:00, an L_{eq} of 69.8 dBA, which is practically the same as the one reported in the present study. Although the number of cars has increased significantly in Mexico City since 1985, they are less noisy.

4. CONCLUSIONS

The results presented above has shown that the two zones of the survey, considered as placed of great tradition in Mexico City, have noise levels that exceed the values recommended by international organizations. The main avenues are equally noisy in both zones; the secondary streets have noise levels higher in zone *B* than in zone *A*. Surprisingly, the noise levels were higher in the plaza of zone *B* than in main avenues of both zones, which is an indication that urban leisure is also a considerable source of noise pollution.

According to the criteria recommended by the World Health Organization and the Organization for Economic Cooperation and Development, the measured noise levels might be a source of annoyance in the users of the studied spaces; however, social studies are required to know the response of Mexicans living in Mexico City to the urban noise.

From a practical point of view, the presented results, although limited to two zones of Mexico City, can be useful to those people involved in taking decisions on urban planning.

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