euronoise

Analysis and evaluation of noise reaction in open public spaces in Mexico City

Miriam German[a], Fernando Greene Castillo[a], J.m. Barrigón Morillas[b] and Arturo Santillan[c]

[a]Universidad Nacional Autonoma de Mexico-Facultad de Arquitectura, Circuito Interior S/N, Ciudad Universitaria, Delegacion Coyoacan, 04510 Mexico D.F., Mexico
[b]Departamento de Física, E. Politécnica, Universidad de Extremadura, Avda. de la Universidad S/N, 10071 Cáceres, Spain
[c]Universidad Nacional Autonoma de Mexico, Centro de Ciencias Aplicadas y Desarrollo Tecnologico, CCADET-UNAM, Circuito Exterior s/n, Cd. Universitaria, A. P. 70-186, 04510 Mexico, D.F., Mexico
lydmgg@yahoo.com.mx

Mexico City, with a population estimated in 19 millions, is part of one of the largest metropolitan areas in the world. Unfortunately, scientific work on urban noise in Mexico City is scarce. A study on people reaction to urban noise carried out in open public spaces of two different zones of Mexico City will be presented. A previous survey in those zones showed that the noise levels exceeded the values recommended by international organizations to protect public health and welfare.
The general objective of the study to be presented was to identify the sound sources perceived by the pedestrians, and to evaluate their response to urban noise pollution in the two mentioned areas. The results show that for most of the people a) urban noise is not considered a relevant aspect to improve these zones of the city, although urban noise has a negative effect on the decision of using open public spaces; b) the people who believe that noise pollution has negative effects are more annoyed; c) vehicular traffic is the most annoying noise source, contributing significantly the public transportation; d) one of the principal strategies to confront urban noise is to get used to it.

1 Introduction

Mexico City and the municipalities of neighboring states form one of the largest metropolitan areas of the world known as the "Metropolitan area of Mexico Valley". It registered a population of approximately 19 million inhabitants in 2005 [1]. This area is the most important centre of governmental, industrial, commercial, financial, and educational activities of the country. Mexico City not only has the highest human concentration of the nation, but it also has the highest concentration of motor vehicles. In 2007 the total number of vehicles was slightly higher than 3 million, 30% more than in 2000 [2]. From the total number of vehicles, private cars and taxis represent 96.5%, cargo transportation 2.6 %, and public transport service 0.9%. In the last decades the street network for the mobility of such amount of vehicles has been increased considerably. At present the extension is larger than 10 thousand kilometers in the city, from which 9% correspond to primary avenues and 91% to secondary streets [2]. A consequence of the increment has been the degradation of the open public spaces (plazas, parks, streets, gardens, etc) from the point of view of the acoustic pollution, which affect the users of these spaces.

During the last years an incipient interest has been observed by public authorities and citizens to promote the rights of pedestrians [3, 4]. However, the proposals have been focused mainly on campaigns dealing with vial education to decrease the number of accidents involving pedestrians, and suggestions to eliminate obstacles to the free transit of people. This fact shows that the problem has not been treated from a holistic point of view as, for instance, in the European Charter of Pedestrians' Rights [5], where environmental aspects that can affect the well being of people have been considered.

Although relevant discussions of the noise problem of Mexico City started in the seventies [6], scientific work and the development of standards against noise have been scarce and limited [7, 8]. Now that the users of the open public spaces in Mexico City start to be considered, it is important to promote their well being from the acoustic point of view.

The present study is part of a Ph.D. research in the field of urbanism made by Ms. German and directed by Mr. Greene. The work carried out consisted in the design and application of a questionnaire in several streets of two traditional zones of Mexico City, which have in common large traffic flows and intense human activities in open public places.

The general objective of the present study was to identify the sound sources perceived by the pedestrians as the most annoying; in addition, to evaluate their responses to urban noise pollution in the streets from the point of view of the following aspects: satisfaction with the surrounding environment, effects caused by noise, beliefs related to noise, noisiness, and strategies to confront street noise.

2 Methodology

The study was carried out in the same two zones of Mexico City where a previous survey was conducted to know the sound levels in a diurnal period [9]. Those areas are 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 areas of similar land use, with residential spaces and commercial establishments along their perimeters and predominantly residential uses in their interior. Main avenues delimit both zones, and secondary streets predominate in their interiors. The *sites* where the questionnaires were applied are identified as A-1, A-2, B-1 y B-2; the letter defines the studied *zone* and the number the type of the street. In this way, '1' corresponds to a primary street and '2' to a secondary street.

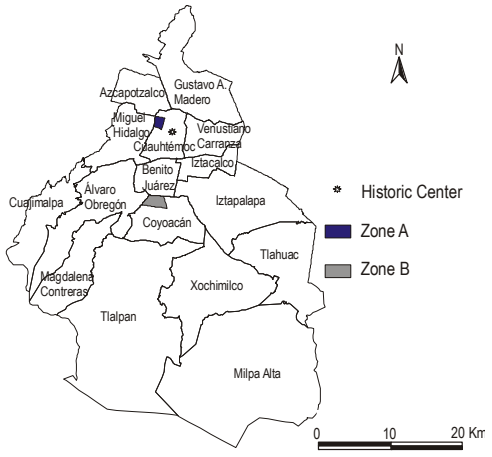

Figure 1. Localization of the studied zones in the map of Mexico City.

An eleven-point (0-10) numerical scale with endpoint markings *none* and *very much* was used. A *verbal* scale of five categories was associated to the numerical scale according to the following breakpoints: 0 + 1 = *none*, 2 + 3 = *a little*, 4 + 5 + 6 = *moderate*, 7 + 8 = *a lot* y 9 + 10 = *very much*. The relationship between the two scales for the different questions showed Spearman correlation coefficients of 0.97 on average ($p < 0.0001$). This indicates that the verbal scale can explain of 94% the variability of the numerical scale on average, which was considered as acceptable for the use of the verbal scale. A previous study showed, for the association of same scales to the one described, a correlation coefficient of 0.73 ($p < 0.0001$) for the responses on annoyance produced by the noise from vehicle transportation [10].

The questionnaire was applied face to face during February 2008, between Mondays and Thursdays from 9 AM to 4 PM. Respondents made their decision to participate without having any knowledge that they would be asked questions on noise. Before the annoyance evaluation produced by the global noise in the site, the equivalent sound pressure level (L_{eq}) during one minute was measured for each interview.

A total of 136 questionnaires were answered by pedestrians older than 16 years, who were randomly selected. The response rates were, on average, 30% in the sites A-1 and B-1, and 37.5% in sites A-2 and B-2.

3 Results and discussion

The results of a descriptive statistical analysis on the satisfaction with the surrounding environment, the annoyance caused by the noise in the streets, and the strategies to confront street noise are presented.

The age distribution of the people in the survey was quite broad, from 16 to 80 years old, with the same proportions of men and women. The mean and the standard deviation in each site were 36 ± 15 in A-1, 41 ± 17 in A-2, 38 ± 15 in B-1, and 34 ±16 en B-2. The groups of ages with the highest percentage of people interviewed were as follows: in A-1 and B-2, the group of people between 16-24 years old with 32% and 41% respectively; in A-2 the group between 25-34 years old with 27%; in B-1, the groups between 16-24 years old and 45-54 years old, both with 27%.

It was found that all the people in the sample had a certain level of education. In fact, the highest percentage of the people interviewed in the primary streets of both studied zones (A-1 and B-1) had high school education, 47% and 35% respectively. Regarding the secondary streets (A-2 y B-2), the largest percentage corresponded to people with undergraduate and graduate studies, respectively, 44% in A-2 and 41% en B-2.

In zone A most of the interviewees live in that area, while in zone B, most of the people in the sample live outside that area. The percentage in both cases was 66%.

Most of the pedestrians found in sites A-1, B-1, and B-2 walked in those sites due to work reasons, respectively, 26%, 58% y 44%. In the site A-2, the same percentage of people, 23%, were in that street for reasons regarding work, commercial activities, and personal administrative formalities.

3.1 Satisfaction with the surrounding environment

The results on the evaluation of the satisfaction are describe in this section concerning the following characteristics of the studied zones: *cleanness*, *air quality*, *citizen security*, *noise during the daytime*, *odors*, *quality of streets and sidewalks*, *freedom to walk along the sidewalks*, and *visual appearance of the streets*.

In each zone, the satisfaction with the majority of the characteristics mentioned in the paragraph above is lower in the answers obtained in the sites located in the primary streets (A-1 and B-1) than in the ones located in the secondary streets (A-2 y B-2). This result suggests that the characteristics of the site where the questionnaire was applied had an influence on the answers. In general, for the eight characteristics evaluated, the people expressed less satisfaction in zone A than in zone B. The characteristic that produced the lowest level of satisfaction was the same among the four sites: *the noise during the daytime*, with mean values of 2.6, 3.6, 3.4, and 5.5 for the sites A-1, A-2, B-1 and B-2 respectively, and standard deviations between 2.3 and 2.7.

No significant difference was found, in terms of the satisfaction with the eight evaluated characteristics of the surrounding environment, between the people who live in the studied zone and those who live outside that zone ($p > 0.05$, Mann-Whitney test).

It is relevant that despite the fact that *the noise during the daytime* was the characteristic evaluated with the lowest level of satisfaction, most of the people did not consider this characteristic as the most relevant aspect to improve those zones of the city. The majority of those people (44% and 26% in zone A and B, respectively) considered that citizen security was the most important aspect. Noise was evaluated in the fifth and fourth positions of importance, respectively, in zone A with only 4% of the answers and in zone B with 13%.

Another relevant aspect that showed the results from the questionnaires is that noise has a clear influence on the decision of people to avoid certain activities outdoors. The answers obtained in the tow highest categories of the verbal scale (*a lot* and *very much*) were considered to define a significant impact of noise on such activities. The results showed that noise has a high impact on 29% of the people interviewed to avoid going to walk in the streets for reasons of pleasure, on 35% to avoid doing exercise outdoors, and on 29% to avoid walking as a means of transportation. Regarding the influence of noise on the decisions of people to do activities outdoors, no significant differences were found amongst the different age groups ($p > 0.05$, Kruskal-Wallis test).

It was interesting to analyze the relationship between the satisfaction with noise and the satisfaction with the other seven evaluated characteristics of the surrounding environment. The correlation coefficients r of Spearman and their significance levels are shown in table 1. Significant relations are observed in 54% of the cases, with positive correlation coefficients, which seems to indicate that the higher the satisfaction with noise, the higher the satisfaction with the other characteristics of the surrounding environment. Although only a small percentage (less than 47%) of the variation in the satisfaction with each of the

characteristics of the surrounding environment is explained by the satisfaction with noise, the results show relevant aspects. In the majority of the sites exist significant relationships between the satisfaction with noise and both air quality and odors. Such relationships have been discussed by Winneke et al [11], who mention that people have a general sensitivity to environmental effects, and by Campbell [12], who suggests that air and pollution and traffic noise can have combined impacts.

In three studied sites, the correlation between the satisfaction with noise and the satisfaction with the visual appearance of the streets is significant. This result seems to agree with the study by Yang [13], who mentions that visual and aural aspects may have certain interactions, working together as an aesthetic comfort factor.

Characteristics of the surrounding environment	Studied sites			
	A-1	A-2	B-1	B-2
Cleanness	0.34*	0.25	0.02	0.14
Air quality	0.53**	0.54**	0.37*	0.67**
Citizen security	0.28	0.29	0.13	0.25
Odors	0.52**	0.57**	0.31	0.69**
Quality/street/sidewalks	0.13	0.21	0.44*	0.42*
Freedom to walk	0.50**	0.26	0.30	0.44**
Visual appearance	0.50**	0.17	0.32*	0.46**

Table 1. Spearman correlation coefficients between the satisfaction with noise and the satisfaction with the other seven evaluated characteristics of the surrounding environment. Marks * and ** indicate significant correlation, with * representing $p \leq 0.05$ and ** representing $p \leq 0.01$.

3.2 Annoyance from street noise

Two kinds of answers for the annoyance evaluation were obtained:

a) Annoyance produced by isolated sound sources (evaluation considering the last times that a person has transited thought the site): 1. horns, 2. public transport service, 3. private cars, 4. motorcycles, 5. music from commercial establishments, 6. sirens from emergency vehicles, 7. street sellers, and 8. voices.

b) Annoyance produced by global noise (noise from all the noise sources) of the studied sites (evaluation carried out at the moment of the application of the questionnaire).

For each site of the study, the percentages of answers (in the verbal scale) of the annoyance produced by the isolated noise sources (1 to 8) and for the general noise (9) are shown in Fig. 2. On average, the sound sources that cause the highest annoyance are related to *vehicular traffic* for the four sites. Similar results have been reported in studies on the annoyance produced by urban noise in residential areas [14-16]. Generally the streets of Mexico City have the problem of traffic congestion. As a consequence, horns and sirens are used excessively. However, it is observed that on average the interviewees are more tolerant to noise from sirens than the noise from horns (26% and 58% of the responses for annoyance were in the category of *very much* for sirens and horns respectively). This result may be explained by the fact that the noise from sirens is not as frequent as the noise from horns; another explanation is that the people consider that the former is necessary and, therefore, it is more annoying than the latter, as has been suggested by previous studies [17, 18].

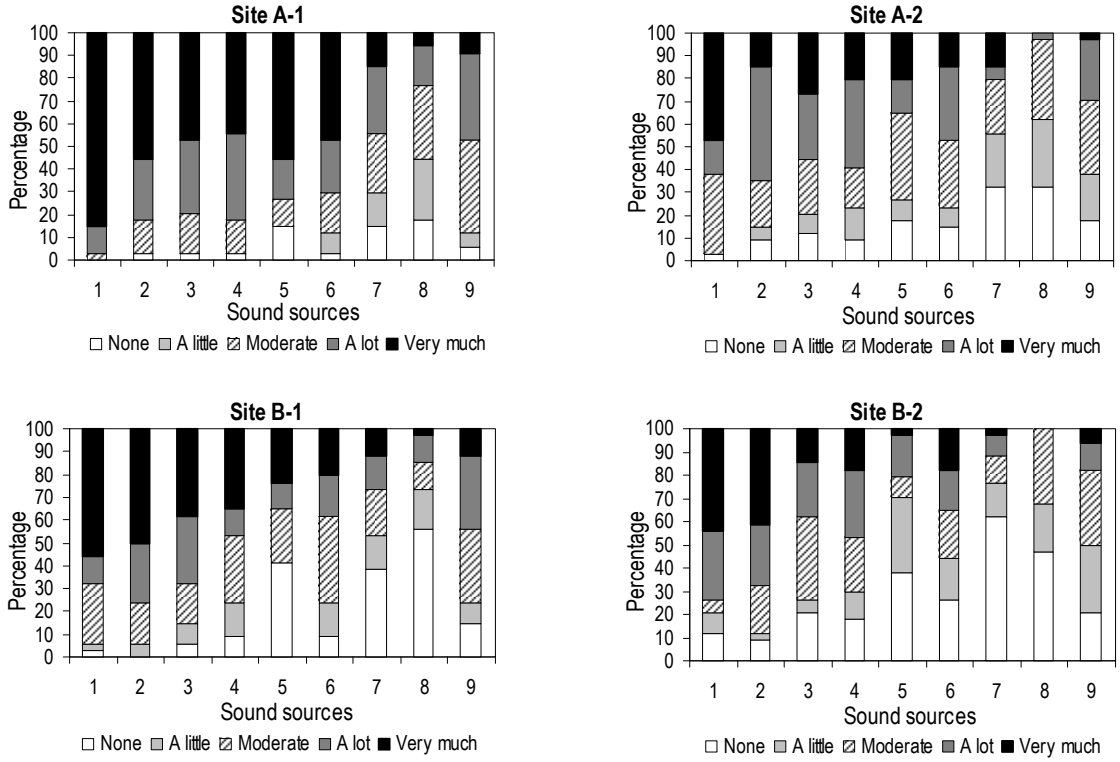

Figure 2. Percentages of answers of the evaluation of noise produced by several noise sources. 1. horns, 2. public transport service, 3. private cars, 4. motorcycles, 5. music from commercial establishments, 6. sirens from emergency vehicles, 7. street sellers, 8. voices, and 9. Global noise.

It can also be observed in Fig. 2 that the people had more tolerance for noise produced by private cars than for noise produced by public transportation. The latter was the second source of noise that, on average, is *very much* annoying (40% of the people gave this evaluation). Public transportation represents only 0.9% of the total number of vehicles that transit in Mexico City [2]. However, it provides a deficient service and, in general, the inhabitants of the city have a negative opinion of that kind of transportation system [19]. This opinion may have an adverse influence on the answers concerning annoyance given by the interviewees besides the high noise levels generated.

With respect to the evaluation of the annoyance produced by the global noise, it is observed in Fig. 2 that in all the studied sites the highest percentages of the answers are in the category of *moderate*. The corresponding answers in the categories of *a lot* and *very much* are higher in the sites located in the primary streets (A-1 and B-1) than in the sites located in the secondary streets (A-2 and B-2). This result is in agreement with the registered noise levels (L_{eq} in dBA). The average of the different values measured of the L_{eq} in the sites located in the primary streets was 71 dBA in both sites A-1 and B-1; in the sites located in the secondary streets, the average was 64 dBA in A-2 and 67 dBA in B-2.

In relation to the belief that noise affects health, the results show that 19% if the interviewees considered that such affectation is in the level of *very much*, 32% corresponded to *a lot*, 29% to *moderate*, 6% to *a little*, and 14% to *none.* In relation to this topic, a previous study on noise from airplanes showed that approximately 35% of the people interviewed considered that noise impairs health [20]; other study obtained that 57% of the interviewees considered that aircraft noise threatens their health *very much* [21]. The relation between this belief and the annoyance produced by the global noise is positive, which seems to indicate that the higher the belief of affectation, the higher the level of annoyance expressed. In the cases in which the evaluation of affectation is lower than five, the evaluation of the annoyance produced is on average four; when the affectation is higher than five, on average the annoyance is six. Although the correlation coefficient is weak ($r = 0.39$), this coefficient is significant to the level of 0.01. This positive and significant relation has also been reported by Karami in the case of aircraft noise [21].

3.3 Strategies to confront street noise

The options presented to the interviewees in the questionnaire of the different strategies to confront street noise (they were asked to choose one they follow) were the following ones: *not to pay attention to the situation*, *to resign oneself to the situation*, *to get used to the situation*, *to get angry with the ones who cause the problem*, *to think that there are worse problems in the city than noise, to blame to the authorities for the problem*.

The majority of the interviewees, 41%, chose as their strategy *to get used*; 20% mentioned *to resign*, 18% *not to pay attention*, 9% *to think that there are worse problems*, 7% *to blamed the authorities*, and 5% *to get angry with the ones who cause the problem*. Ruiz [22] reports that the best strategies to confront the stress produced by the noise perceived at home are those focused on emotions (evasion, positive thoughts, resignation, etc.) and, in a less common way, those consisting in confront the problem actively.

The effect of the strategy on the evaluations of the belief of health affectation and annoyance was analyzed. The answers of the strategy were considered in four groups: *to get used, to get resign, not to pay attention,* and *others* (it includes the answers corresponding to the other three evaluated strategies). The Kruskal-Wallis test showed that there is no significant difference among those groups for the case of the belief of heath affectation, but such difference exists for the answers of annoyance ($p > 0.05$ and $p = 0.05$ respectively). However, in the first case, the people who have as their strategy *to get resign* and *to get used* give higher evaluation of annoyance than those who try *not to pay attention* or use *other* strategies (means of 6 for *to get resign,* 7 for *to get used*, and five for both *not to pay attention* and *others*). In the second case the same effect is observed; *to get resign* and *to get used* have a mean of five, and *not to pay attention* and *others* have a mean of four. In this sense, Guski [17] mentions that the strategies used to confront noise indirectly can be very effective in the reduction of the annoyance. The results of Kuwano [23] show that those who answered that it was difficult for them to be habituated to noise tended to be more annoyed by noise.

4 Conclusions

The results presented above have shown that despite the fact that noise is not considered as the most relevant aspect to improve the conditions of the studied zones, it has influence on the decision of people to avoid carrying out certain outdoor activities.

The relationship between the satisfaction with noise and both the satisfaction with environmental aspects and the satisfaction with the visual characteristics of the surrounding environment was positive and significant; however, the correlation coefficients were relatively week.

The sound sources that produced the highest level of annoyance are related with the vehicle traffic; nevertheless, it was observed a higher impact produced by the noise from horns and public transportation than by the noise from sirens and from private cars.

The annoyance produced by global noise was more intense in the sites located in the primary streets than in the sites of secondary streets, which was consistent with sound levels registered.

The people who gave evaluations of intense affectation of their health produced by noise are the ones who reported the highest levels of noise annoyance. One of the main strategies to confront noise is to get used to it; however, those who follow this strategy gave the answers showing the highest levels of annoyance and of affectation on their health.

Acknowledgments

The authors would like to thank to Consejo Nacional de Ciencia y Tecnología of Mexico for the financial support provided to carry out the present work, and to Universidad Nacional Autónoma of Mexico and to The French Department of European and Foreign Affairs for the

economic support given to the first author to participate in the Conference Acoustics 08 Paris.

References

[1] Instituto Nacional de Estadística, Geografía e Informática (INEGI), "II conteo de población y vivienda 2005". Retrieved October 10, 2006 from http://www.inegi.gob.mx

[2] Secretaría de Transporte y Vialidad (SETRAVI), "Informe enero-abril de 2007". Retrieved May 15, 2007 from http://www.setravi.df.gob.mx/

[3] Centro de Transporte Sustentable. "Proyecto: Transporte no motorizado". Retrieved February 10, 2007 from http://ctsmexico.org/tnm01.htm

[4] E. Gallegos Pérez, "Preparan legisladores del DF una ley que proteja al peatón", *Diario La Razón*, May 5, 2007. Retrieved October 2, 2007 from: http://www.diariolarazon.com.mx/portal/article.php?story=20070305150001335&mode=print

[5] WHO. "Directory of resources on transport, health and environment in developing countries". Retrieved February 10, 2008 from:

http://www.who.int/heli/risks/urban/transpdirectory/en/index8.html

[6] J. Legorreta, "Transporte y contaminación en la Ciudad de México", *Centro de Ecología y Desarrollo*, México 1995

[7] R. R. Boullosa, S.J. Perez Ruiz, "An exploratory study of Community noise levels in Mexico City", *Appl Acoust.* 22, 271-280 (1987)

[8] Norma Oficial Mexicana NOM-081-ECOL-1994, "Limites máximos permisibles de emisión de ruido de las fuentes fijas y su método de medición", *Secretaría de Desarrollo Social*, México, 1995

[9] M. German González, F. Greene Castillo, A. O. Santillán, "Analysis and evaluation of environmental noise conditions in two different areas in Mexico City", *14th International Congress on Sound and Vibration*, Cairns Australia 9-12 July (2007)

[10] D. S. Michaud, S. E. Keith, D. McMurchy, "Annoyance and disturbance of daily activities from road traffic noise in Canada", *J. Acoust. Soc. Am.* 123 (2), 784–792 (2008)

[11] G. Winneke, M. Neuf, B. Steinheider, "Separating the impact of exposure and personality in annoyance response to environmental stressors, particularly odours", *Environmental International* 22, 73-81 (1996)

[12] J. M. Campbell, "Ambient Stressors", *Environment and Behavior* 15, 355-380 (1983)

[13] W. Yang, J. Kang, "Acoustic comfort evaluation in urban open public spaces", *Appl Acoust.* 66, 211–229 (2005)

[14] P. H. T. Zannin, et al, "A survey of urban noise annoyance in a large Brazilian city: the importance of a subjective analysis in conjunction with an objective analysis", *Environmental Impact Assessment Review* 23, 245-255 (2003)

[15] M. A. Martín, "Exposure effect relationships between road traffic noise annoyance and noise cost valuations in Valladolid, Spain", *Appl Acoust.* 67, 945-958 (2006)

[16] M. U. Onuu, "Road traffic noise in Nigeria: Measurements, analysis and evaluation of nuisance", *J Sound Vibr.* 233, 391-405 (2000)

[17] R. Guski, "Personal and social variables as co-determinants of noise annoyance", *Noise & Health* 3, 45-56 (1999)

[18] M. Fields, "Effect of personal and situational variables on noise annoyance in residential areas", J. *Acoust. Soc. Am.* 93 (5), 2753-2763 (1993)

[19] D. Canal y Soto, "Los microbuses, nudo ciego del transporte popular en el D.F.", *Revista Gente Sur*, December 15, 2005; 15. Retrieved March 25, 2007 from: http://www.gentesur.com.mx/articulos.php?id_sec=7&id_art=461

[20] R. F. S. Job, J. Hatfield, "Effective communication on health messages regarding noise-induced health effects", *Noise & Health* 2, 33-38 (2000)

[21] K. Karami, S. Frost, "Nuisance caused by aircraft noise in the vicinity of Tehran International Airport", *Environmental Management and Health* 10 (2), 90-95 (1999)

[22] C. Ruiz, B. Hernández, E. Hernández-Fernaud, "Estrategias de afrontamiento al estrés producido por el ruido percibido dentro de la vivienda", *Medio Ambiente y Comportamiento Humano* 5 (1 y 2), 133-152 (2004)

[23] S. Kuwano, M. Morimoto and T. Matui, "A questionnaire survey on noise problems with elderly people", *Acoust. Sci. & Tech.* 26 (3), 305-308 (2005)