Acoustical factors influencing noise annoyance of urban population

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INTRODUCTION

Noise annoyance is a feeling of displeasure (“nuisance”, “disturbance” or “irritation”) caused by noise, which affects people’s quality of life. Several characteristics of noise – its level, source, and number of noise events, are associated with noise annoyance. Noise annoyance is a major public health problem, since 24 million people (out of 380 million) in the European Union are highly annoyed by road traffic noise higher than 55 dB for 24 hours (L_{dn}) (EEA 2000). Noise measurements performed in Belgrade in the last 30 years indicate that noise limits are exceeded by 11-16 dB in daytime and by 10-14 dB at night (Institute of Public Health of Belgrade 2002). However, the extent of noise annoyance in Serbian population is not known. In the near future Serbia will implement several environmental regulations, including the Directive 2002/49/EC of the European Parliament and of the Council, relating to the assessment and management of environmental noise (Directive 2002/49/EC, 2002). Therefore, this is the first study on noise annoyance in Serbian population.

The aim of this study was to assess the effect of acoustical factors influencing noise annoyance of residents of city centre of Belgrade, Serbia.

METHODS

The study was performed in city centre of Belgrade, on a sample of 1,836 adults (mean age 46±23 years): 776 men and 1,060 women. Investigators distributed a questionnaire on noise annoyance to flat owners, and collected them the other day. Noise annoyance was assessed using a self-reported numerical scale (range 0-10), and high-level noise annoyance was described as score ≥ 6. Subjects were asked to rate the most important sources of noise in their environment. All questionnaires were anonymous.

Noise was measured in all 70 streets of the municipality, using Noise Level Analyzer type 4426 “Brüel & Kjær” (ISO 1982). Equivalent noise levels [Leq (dBA)] were measured in two day intervals, an evening interval, and two night intervals. Time interval of each measurement was 15 minutes; the speed of sampling was 10 per second, with 9,000 samples collected per measurement at one site. From the obtained Leq levels, we calculated composite daytime Leq, evening Leq, nighttime Leq, and 24-hour Leq for each street and maximal noise levels (Lmax) at daytime and nighttime. Traffic density at each site was measured by counting light and heavy vehicles per hour.

Descriptive statistic is presented as mean values ± standard deviation (SD) for numeric variables, or as percents (relative numbers) for categorical variables. The differences between groups were tested using Chi-square test and Mann-Whitney U test. The association between mean score on annoyance scale and noise characteristics was measured by Pearson's correlation coefficient. Univariate logistic regression was performed to calculate odds ratios for high-level annoyance in relation to relevant independent variables. The influence of noise characteristics on high-level annoyance was estimated using multivariate logistic regression.

RESULTS

The population was highly annoyed by noise: mean score on noise annoyance scale was 7.14±2.07 for men, and 7.23±3.05 for women. In total, nearly 36 % of the population was highly annoyed by noise (Table 1). Highly annoyed and less annoyed groups were comparable by age, gender, education, and residential characteristics (flat size and years of residence).

Table 1: Basic characteristics of investigated population

The most important noise sources	Less annoyed	Highly annoyed	Total	p value
Number of subjects	1,169 (63.7 %)	667 (36.3 %)	1,836 (100.0 %)	
Gender (male)	468 (40.0 %)	256 (38.4 %)	724 (39.4 %)	0.421*
Age (years)	45.7±20.3	47.6±17.8	46.2±23.1	0.741†
Education	724 (61.9 %)	373 (55.9 %)	1,097 (59.7 %)	0.058*
Flat size	65.7±24.0	63.8±25.7	64.3±25.6	0.066†
Years of residence	18.4±16.1	17.3±14.8	17.8±15.3	0.483†

* Chi-square test

† Mann-Whitney U test

The most important noise sources are represented in Table 2. More than a half of all residents identified road traffic as the most important source of noise, but significantly more highly annoyed residents (63.3 %), than less annoyed persons (51.6 %). Second most important source of noise were construction works in the street, and they were more important for less annoyed residents. Neighborhood noise, industrial facilities and electrical appliances in buildings were least important sources of noise in the investigated population.

Table 2: Subjective rating of noise sources of investigated population

The most important noise sources	Less annoyed	Highly annoyed	Total	p value
Road traffic	603 (51.6 %)	422 (63.3 %)	1025 (55.8 %)	<0.0001*
Construction works in the street	275 (23.5 %)	104 (15.6 %)	379 (20.6 %)	0.004*
Neighborhood noise	192 (16.4 %)	100 (15.0 %)	292 (15.9 %)	0.216*
Industrial facilities	49 (4.2 %)	36 (5.4 %)	85 (4.6 %)	0.737*
Electrical appliances & elevators	96 (8.2 %)	38 (5.7 %)	134 (7.3 %)	0.202*

* Chi-square test

In the whole population, noise annoyance was strongly correlated with nighttime noise level (Leq) and number of heavy vehicles during night. Besides, 24-hour noise, daytime and evening noise, as well as number of vehicles at day and night, were alos significantly correlated to mean annoynace score (Table 3).

Table 3: Correlation coefficients between noise characteristics and mean score on noise annoyance scale of investigated population

Noise characteristics	Correlation coefficients*	p value
Nighttime noise level (dBA)	0.135	<0.0001
Number of heavy vehicles during night	0.129	<0.0001
Maximum noise at night (dBA)	0.099	<0.0001
24-hour noise level (dBA)	0.090	<0.0001
Evening noise level (dBA)	0.085	<0.0001
Daytime noise level (dBA)	0.084	<0.0001
Number of heavy vehicles during day	0.081	<0.0001
Number of light vehicles during day	0.074	0.001
Number of light vehicles during night	0.073	0.001
Maximum noise at night (dBA)	0.013	0.542

***** Pearson's correlation coefficient

Logistic regression identified nighttime noise level and number of heavy vehicles as the strongest predictors of high-level noise annoyance of urban population (Table 4).

Table 4: Odds Ratios (95% Confidence Interval) for high-level noise annoyance* in relation to noise characteristics of investigated population, adjusted for age and gender

Noise characteristics†	OR	95 % CI	p value
Nighttime noise level (dBA)	1.026	1.011-1.042	0.001
Number of heavy vehicles during night	1.015	1.000-1.010	<0.0001

* High-level noise annoyance defined as mean score on annoyance scale ≥ 6

† Variables in model: Age, Gender, Nighttime noise level, Evening noise level, Daytime noise level, 24-hour noise level, Number of light vehicles during night, Number of heavy vehicles during night, Number of light vehicles during day, Number of heavy vehicles during day

DISCUSSION

There are numerous evidences for dose-effect relationship between noise level and annoyance level (Fidell et al. 1991; Bjorkman 1991; Sato et al. 1999; Klæboe et al. 2004). Miedema & Oudshoorn (2001) developed a mathematical model that can predict the percentage of persons annoyed by noise level. Noise exposure in these studies was described as either composite day-night Leq level (L_{dn}) or composite day-evening-night noise level (L_{den}). Most of these authors studied road traffic, aircraft and railway noise separately. In our study, when all noise characteristics are considered, nighttime noise was the strongest independent predictor for noise annoyance. This finding may be explained by the fact that residents of urban areas usually spend their daytime at work, whereas they spend most of their evenings and nights at home.

Another important noise characteristic is the number of noise events. Our study shows that number of vehicles during nighttime and daytime correlate with annoyance, but the most important is the number of heavy vehicles at nighttime. This is similar to the findings of Björkman (1991), who reported increase of the extent of annoyance with the increase of noise events, and suggested that the number of heavy vehicles can be a good indicator of the number of noise events for road traffic noise. The relationship between noise annoyance and nighttime number of noisy events was also confirmed for aircraft noise (Quehl & Basner 2006). On the other hand, Sato et al. (1999) found strong relationship between noise annoyance caused by road traffic noise and noise levels, but not with the number of noise events.

In comparing the different means of transportation, noise from road traffic is more annoying than that from the railroad (Ouis 2001). On the other hand, Kurra et al. (1999) found that railway noise was the most prominent noise source in the overall annoyance, but also concluded that the source type was not a highly deterministic factor while the respondents were concentrating on daily work at home.

However, we find that various sources of noise should not be observed separately. Miedema (2004) suggested a model concerning noise annoyance from combined sources (aircraft, road-traffic and railway noise). In our study, we considered road traffic noise to be the most important, and we measured equivalent noise levels for road traffic noise. Nevertheless, based on the responses from our subjects, sources of noise other than traffic, such as neighborhood noise, are probably equally important. Therefore, one limitation of this study is that we did not include noise emitted from other sources that our residents consider important.

CONCLUSIONS

In conclusion, this cross-sectional study on an adult population of a Belgrade municipality showed significant association between nighttime road-traffic noise and high noise annoyance of urban residents.

We suggest the use of nighttime noise level as exposure indicator for noise annoyance assessment. Nighttime noise countermeasures might also have a greater public health impact compared to daytime, including a possible influence on the incidence of noise annoyance in urban population.

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