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NOISE ANNOYANCE IN ADULT URBAN POPULATION – A DISCREPANCY BETWEEN THEORY AND PRACTICE

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Noise annoyance in adult urban population has not been well-studied in Serbia. The aim of this paper is to assess the proportion of noise annoyance in urban population. Furthermore, the objective was to compare empirical results with theoretical estimations computed from the formulas from the Ordinance on noise indicators of the Republic of Serbia 75/2010. The study was undertaken in Belgrade, the Municipality of Stari Grad, from 2006 to 2010. The sample consisted of 3.093 persons (1.214 men and 1.879 women), aged 42.19±17.88 years. Noise levels were measured in all the streets, and day-evening-night equivalent noise level was calculated (Lden). Noise annoyance was assessed in the population (epidemiological results) using a verbal scale, and calculated using formulas from the Ordinance 75/2010 (theoretical results).

In total, 1.134 persons (36.7% of the investigated population) were highly annoyed by road-traffic noise. The proportion of highly annoyed persons estimated in the epidemiological research was by 10-20% higher than the proportion obtained from theoretical estimations, for a given Lden range from below 50 dB(A) to above 75 dB(A). The study reveals a discrepancy between epidemiological and theoretical estimations of noise annoyance in the population of Stari Grad Municipality in Belgrade. Future research should attend to harmonize theoretical models with empirical data, taking into account all the factors influencing the occurrence of noise annoyance in the population. *Acta Medica Medianae 2013;52(3):12-17.*

Key words: *noise, road traffic, noise annoyance*

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Introduction

Noise annoyance is a specific psychophysiological reaction to noise exposure, described as a feeling of displeasure, nuisance, disturbance, irritability, anxiety, frustration and anger caused by certain sounds (1). Noise (unwanted sound) is the only environmental factor that causes annoyance in humans. Noise annoyance reaction depends on the type of noise sources such as road or air traffic, industrial facilities, construction works on the streets, etc., on noise characteristics (level, frequency, number of noise events). Furthermore, it depends on several psychological traits of the exposed persons (personality characteristics, noise sensitivity, attitudes toward noise), as well as on the conditions of noise exposure (place, time and type of exposure, presence of noise protection, etc.) (1- 4).

The estimated proportion of people disturbed by noise is very high throughout the world and is further increasing as a result of intensive urbanization. About 25 million citizens of the European Union reported being highly annoyed by road-traffic noise in the year 2000 (5). By the year 2007, however, that number grew to 50 million people, or about 20-25% of the entire population of the member countries (6).

A new law on the protection from environmental noise was implemented in Serbia in 2009 (7). This law complies with international regulations on environmental protection, primarily with the European Union Directive 2002/49/EC relating to the assessment and management of environmental noise (8). The following year, 2010, the country adopted the Ordinance on noise indicators, limits, methods for evaluating noise indicators, annoyance and adverse effects of environmental noise (hereinafter Ordinance 75/2010) (9). This ordinance introduces a new principal noise indicator, i.e. Lden – equivalent sound level for day, evening and night, instead of previous indicators, such as equivalent noise levels for daytime and for nighttime (Leq). It also obliges authorities to determine the occurrence of two harmful effects of noise, namely noise annoyance and sleep disorders in general population.

In Serbia so far, there have just been a few studies on the incidence of noise annoyance in the population (3,4). To the author's knowledge, there are no official estimations of noise annoyance based on the aforementioned regulation. The author, therefore, wanted to determine whether the data on the proportion of noise annoyance obtained from an epidemiological survey coincide with similar estimates derived from a formula proposed by the Ordinance 75/2010.

The aim of this study was to determine the frequency of noise annoyance in urban population and to compare these empirical data with the theoretical estimate of the frequency of noise annoyance under Ordinance 75/2010.

Material and methods

The research was conducted in the Municipality of Stari Grad in Belgrade from 2006 to 2010. This municipality was chosen because of its relatively small size, apparent borders, and stable socio-demographic structure. More importantly, road-traffic noise is the dominant source of noise in this municipality. The total population of the municipality amounted to 60,000 inhabitants according to the census in year 2002. Randomized sample of 6.000 inhabitants was obtained by dividing the questionnaire into mailboxes of every tenth apartment in all the streets. In total, 3.133 questionnaires were collected (acceptance rate of participation in the study, 52.2%). Incompletely fulfilled questionnaires were excluded from the study, so that the final sample consisted of 3.093 persons (1.214 males and 1.879 females), mean age 42.19±17.88 years (range 18-90 years).

Noise measurement was carried out in all the streets of this municipality in the period from 2006 to 2009. Noise Level Analyzer type 4426 "Brüel & Kjær" was used in accordance with the recommendations of the International Organization for Standardization (10). Equivalent noise levels (Leq) were measured twice a day (between 8 and 10 a.m. and between 2 and 4 p.m), once in the evening (between 6 and 8 p.m.) and twice during the night (between 10 and 12 p.m. and between 2 and 4 a.m.). Each measurement interval lasted for 15 minutes, and sampling rate was set at 10 per second. Thus, the total number of samples equaled 9000 per interval on each measurement point. From the obtained equivalent noise levels the average values of Leq_day, Leq_evening and Leq_night were calculated for every street.

Furthermore, using these values and the formula provided in the Ordinance 75/2010, an equivalent noise level for day, evening and night (Lden) was calculated. This is considered a reliable indicator of environmental noise level. All noise levels are expressed in dB(A), which is a unit of A-weighted sound level for the corresponding periods of time (9).

Noise annoyance in the population of Stari Grad was assessed using a verbal annoyance scale, as recommended by the International Commission for the Biological Effects of Noise (11). This scale refers to annoyance by road-traffic noise at respondent's residence during the previous year. The scale is graded from 0 to 4 as follows: 0 - not at all annoyed, 1 – a little, 2 – moderately, 3 – very, and 4 – highly annoyed. For statistical purposes, respondents who answered "very" or "extremely" were merged into the "highly annoyed" category, while other respondents were considered "not being annoyed by noise". The percentage of highly annoyed persons is a valid indicator of noise annoyance in the population under Ordinance 75/2010 and following the recommendations of the World Health Organization (9, 12).

In order to compare the empirical data with theoretical estimates, the percentage of people highly annoyed by noise from road traffic (% HA) was calculated using the formula set out in Ordinance 75/2010, which reads:

$$\%HA=9.868*10^{-4}*(Lden-42)^3 - 1.436*10^{-2} *(Lden-42)^2 + 0.5118*(Lden-42)$$

Descriptive statistics are presented as mean values ± standard deviation (SD) for numeric variables, or as percents (relative numbers) for categorical variables. Differences between groups were compared using Chi-square test. SPSS 15.0 for Windows software was used for all data analyses (SPSS Inc. 1989-2006).

Results

Basic characteristics of the study population and the average noise levels measured in the study municipality are shown in Table 1. The study comprised 3.093 adults aged 42.19 ± 17.88 years, range 18-90 years, of whom 60% were female and 40% male. About 95% of survey respondents reported having more than 12 years of education or having completed high school (40%), high school (14%) or university (40%).

The average equivalent noise levels during the day, evening and night, as well as the equivalent noise level for day, evening and night (Lden) ranged between 50 and 60 dB (A) (Table 1).

Using verbal annoyance scale, 864 people (27.9%) reported being very annoyed by noise, while 270 people (8.7%) reported being extremely disturbed by road-traffic noise (Table 1). In total, 1.134 persons (36.7%) of the investigated population were highly annoyed by road-traffic noise.

Table 2 presents the proportion of people highly annoyed by noise in an epidemiological study and a theoretical estimation obtained from the formula in Ordinance 75/2010, based on the value of the equivalent noise level for day, evening and night Lden.

Table 1. Basic characteristics of the investigated population and noise levels on Stari Grad Municipality

Characteristics		Number (%)	Mean ± Standard Deviation
Gender	Male	1214 (39.2)	
	Female	1879 (60.8)	
Age (years)			42.19±17.88
Education	Primary school	90 (2.9)	
	Secondary school	1257 (40.6)	
	High school	437 (14.1)	
	University degree	1236 (40.0)	
	Unknown	73 (2.4)	
Noise annoyance	Not at all	214 (6.9)	
	A little	634 (20.5)	
	Moderately	1111 (35.9)	
	Very	864 (27.9)	
	Extremely	270 (8.7)	
Equivalent noise level at daytime (dB(A))			61.67±5.84
Equivalent noise level at evening (dB(A))			56.34±7.22
Equivalent noise level at nighttime (dB(A))			51.16±8.39
Equivalent noise level at day, evening, night Lden (dB(A))			60.52±6.79

Table 2. Number and proportion of highly annoyed persons in the epidemiological study and according to theoretical estimations from the Ordinance 75/2010

Equivalent noise level at day, evening, night Lden	Epidemiological results on Stari Grad Municipality	Theoretical results according to Ordinance 75/2010	Chi-square test	p value
	Number (proportion) of highly annoyed persons	Number (proportion) of highly annoyed persons		
Below 49.9 dB(A)	820 (26.5%)	77 (2.5%)	719.82	<0.001
50.0-54.9 dB(A)	832 (26.9%)	152 (4.9%)	558.81	<0.001
55.0-59.9 dB(A)	928 (30.0%)	254 (8.2%)	475.11	<0.001
60.0-64.9 dB(A)	906 (29.3%)	402 (13.0%)	246.28	<0.001
65.0-69.9 dB(A)	1070 (34.6%)	622 (20.1%)	163.28	<0.001
70.0-74.9 dB(A)	1472 (47.6%)	934 (30.2%)	196.87	<0.001
Above 75.0 dB(A)	1339 (43.3%)	1367 (44.2%)	0.52	0.473

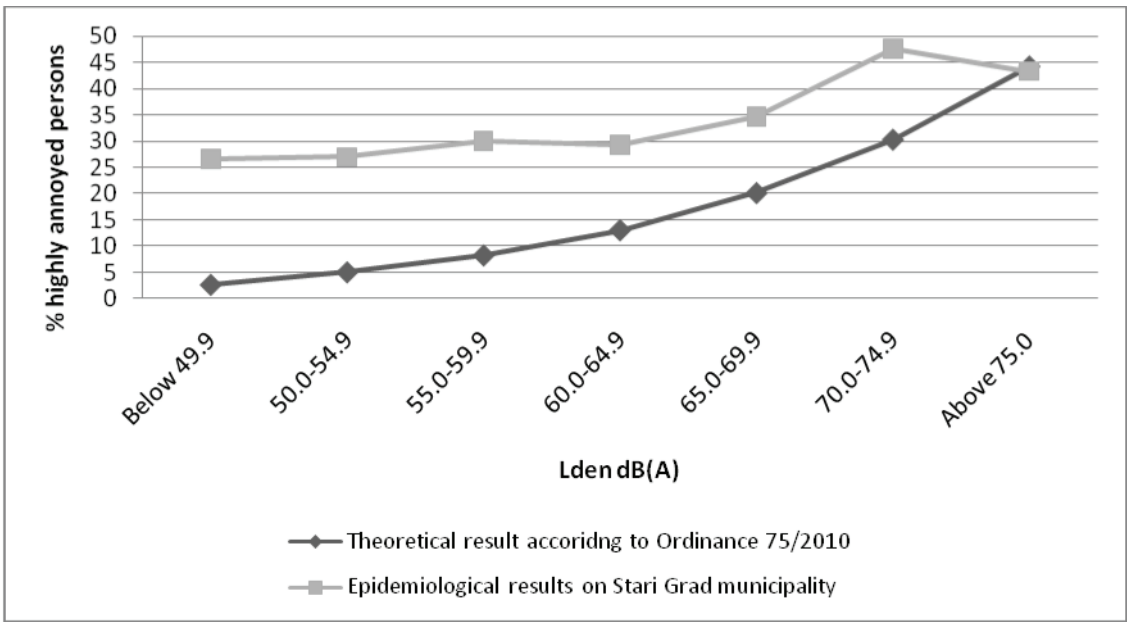

Figure 1. Proportion of highly annoyed persons based on epidemiological data theoretical estimations

The proportions of highly annoyed persons in the epidemiological study were by 15-25% higher than the proportion obtained from the formula for almost all noise levels (Table 2). The differences in the proportion of highly annoyed persons obtained from epidemiological study and from theoretical estimations are highly statistically significant for noise levels from below 49.9 dB(A) to 74.9 dB(A) ($p<0.001$). The only similarity between the empirical and theoretical results can be seen at noise levels above 75 dB(A), when about 43-44% of the population are highly annoyed by noise ($p>0.05$; Table 2).

Figure 1 illustrates the abovementioned similarities and differences in the proportions of highly annoyed person obtained in epidemiological studies and the proportions calculated from theoretical formula..

Discussion

Noise represents a serious environmental problem, because it exerts various adverse effects on human health, including noise annoyance, sleep disturbance, change in blood pressure, stress reactions, disruption of hormone levels and reduced quality of life (1,13). Prolonged exposure to stress-inducing effects of noise can affect the mental health of the population in terms of the occurrence of depressed mood or neurosis (14).

Allowable noise levels in Belgrade in the past 30 years have been exceeded by 2-10 dB(A) during the day and 1-16 dB(A) during the night (15). Many researchers have shown evidence of a dose-dependent relationship between noise levels and annoyance. The most famous among them is Henk Miedema, who developed a mathematical model to predict the proportion of highly annoyed persons using equivalent noise levels for day, evening and night (Lden) (16). His calculations of health effects of noise originating from road-traffic, aircraft and rail transport are included in the European Union Directive 2002/49/EC relating to the assessment and management of environmental noise, as well as in the Ordinance on noise indicators, limits, methods for evaluating noise indicators, annoyance and harmful effects of environmental noise (8,9). Unfortunately, the Ordinance 75/2010 contains errors in English translation and typos in formulas, which the author has suggested to the Ministry of Environment, Mining and Spatial Planning in 2012 (personal correspondence).

Comparing the results of epidemiological studies of the population of Stari Grad with theoretical calculations based on this formula, the differences in their predictions become obvious. The proportion of highly annoyed persons in the population of Stari Grad is much higher than would be expected on the basis of theoretical calculations for all noise levels below 50 dB(A) to over 75 dB(A).

Researchers in the Spanish cities of Granada and Malaga have also reported that the high prevalence of annoyed population was much higher than predicted by mathematical models (17). This divergence may arise from methodological differences in various studies. For example, noise measurements could have been different; noise annoyance could have been estimated using incomparable scales, or the characteristics of road-traffic noise could have been diverse in terms of the number and characteristics of vehicles, acoustic characteristics of roads, etc. (2). On the other hand, there are several personality factors that may affect one's perception of noise and/or attitudes towards it. The most important non-acoustical factor that explains the occurrence of noise annoyance is noise sensitivity (3,4,18). In addition, housing conditions play a distinctive role because they characterize noise exposure. They include window orientation toward the street, window insulation capacity, and the floor level on which the apartment is located (3,4).

Finally, the attitude of people towards the noise source can significantly affect their psychological defence mechanisms and adaptation to noise (18). Once people perceive sound as unpleasant, unpredictable, and without the possibility of control, they react with psychological stress and develop negative affective reactions that we describe as annoyance (18). Not surprisingly, some studies show that people are much more disturbed by neighbourhood noise, noise from construction works on the street, noise from entertainment and leisure facilities, as well as from noise created by other humans and animals (17,19,20). All of these sounds can be annoying because they mask other sounds, distract mental activities, disrupt attention and concentration, and induce secretion of stress hormones (18). Although such sources of noise disturb people more intensively than traffic noise does, their effects on health are not easily measured. This is the reason why researches lack mathematical models on the relationship between levels of such types of noise and the occurrence of noise annoyance in the population.

Conclusion

The presented study shows the gap between epidemiological data and theoretical estimates of the proportion of noise annoyance among the urban population of Stari Grad Municipality in Belgrade. The prevalence of highly annoyed persons in the investigated population was much higher than expected on the basis of theoretical calculations set out in Ordinance 75/2010 for all levels of noise during the day, evening and night. We recommend that future research should aim to synchronize the theoretical calculations with empirical data, taking into account all the factors that cause noise annoyance. In keeping with this, action plans for noise reduction in urban areas and noise protection measures would make a substantial impact on people's health and well-being.

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UZNEMIRAVANJE BUKOM KOD ODRASLOG GRADSKOG STANOVNIŠTVA – RASKORAK IZMEĐU TEORIJE I PRAKSE

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Učestalost pojave uznemiravanja bukom odraslog gradskog stanovništva nije dovoljno istražena u Srbiji. Cilj rada bio je utvrđivanje učestalosti pojave uznemiravanja bukom među gradskim stanovništvom i poređenje empirijskih podataka sa teoretskom procenom prema Uredbi 75/2010. Istraživanje je sprovedeno na teritoriji opštine Stari grad u Beogradu u periodu od 2006. do 2010. godine. Uzorak je obuhvatio 3093 osobe (1214 muškaraca i 1879 žena), prosečne starosti 42,19±17,88 godina. Merenje nivoa buke izvršeno je u svim ulicama ove opštine i izračunat je ekvivalentni nivo buke za dan, veče i noć (Lden). Uznemiravanje bukom procenjeno je verbalnom skalom u populaciji (epidemiološki rezultati) i na osnovu formule date u Uredbi 75/2010 (teoretski rezultati).

Utvrđeno je da su 1134 osobe (36,7% populacije) visoko uznemirene drumsko-saobraćajnom bukom. Učestalost visoko uznemirenih osoba prema epidemiološkim podacima je mnogo veća od teoretskih proračuna za sve nivoe buke od ispod 50 dB(A) do preko 75 dB(A). Ova studija pokazuje da postoji raskorak između učestalosti pojave uznemiravanja bukom među gradskim stanovništvom procenjene u epidemiološkom istraživanju na populaciji opštine Stari grad u Beogradu i učestalosti uznemiravanja bukom procenjene formulom datom u Uredbi 75/2010. Buduća istraživanja treba usmeriti ka usaglašavanju teoretskih proračuna sa empirijskim podacima, vodeći računa o svim činiocima koji dovode do pojave uznemiravanja bukom u datoj populaciji. *Acta Medica Medianae 2013;52(3):12-17.*

Ključne reči: *buka, drumski saobraćaj, uznemiravanje bukom*

