Does bedroom windows orientation contribute to annoyance and sleep disturbance? A questionnaire survey

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ABSTRACT

Sleep disturbance and annoyance, mostly related to road traffic noise, comprise the main burden of environmental noise in Europe. This paper presents the results of a cross-sectional study – a questionnaire survey focused on those issues among the residents living in major Slovak towns including Bratislava and Kosice. Noise annoyance was subjectively assessed by a modified standardized questionnaire obtained electronically and by correspondence from 543 respondents, the average age was 45± 4 years, 53% females, 81% living in houses for more than five years. The questionnaire was supplemented by traffic noise-measurements on noisy and quiet facades ($L_{Aeq,day}$ = from 51.8 dB to 72.4 dB, $L_{Aeq,night}$= from 41.9 dB to 64 dB). Inhabitants from the exposed group with bedroom windows facing noisy streets are less satisfied with their quality of living, are less noise sensitive and report more day and night annoyance and sleeplessness (OR=2.54; 95 % CI =1.38–4.92) than respondents with bedroom windows facing quiet streets. It is necessary to propose interim measures to noisy facades as well as intervention procedures and to apply the principles of healthy city planning.

INTRODUCTION

Environmental noise is an important public health issue, featuring among the top environmental risks to health. It has negative impacts on human health and well-being and is a growing concern among both the general public and policy-makers in Europe. Based on the assessment threshold specified in the Environmental Noise Directive of the European Union, at least 100 million people in the EU are affected by road traffic noise, and in western Europe alone at least 1.6 million healthy years of life are lost as a result of road traffic noise. According to the WHO and the Environmental burden of disease (EBoDe) approach, traffic noise exposure features cause an annual loss of 31 Disability-Adjusted Life Years per 100 000 population in the WHO European Region [1]. In the previously published LARES study in panel block buildings in three cities of Eastern Europe noise represents a traditional urban problem and noise annoyance and

sleep disturbance were recognized as the most prevalent problems affecting residential health and well-being [2].

The review of Basner et al., 2018 demonstrated the effects of traffic noise on objectively measured sleep physiology and on subjectively assessed sleep disturbance (including sleep quality, problems falling asleep, and awakenings during the night) and the link between acute noise-induced sleep [3].

Health effects were identified also for selected physical and stress-related symptoms, such as hypertension and migraine, which showed significantly increased relative risks. The results also indicated that particular attention must be paid to night-time noise exposure in homes [2, 3].

This paper presents the results of a cross-sectional study – a questionnaire survey focused on those issues among the residents living in major Slovak towns including Bratislava and Kosice.The paper presents the results of a pilot cross-sectional study focused on subjective traffic noise annoyance and sleep disturbance among the residents living close to major inner-city corridors in major Slovak towns. The subjective adaptation to traffic noise, subjective evaluation of health status and well-being were assessed as well.

METHODS

Objective measurements of noise in the external facades of selected residential buildings were performed as a continuous 24 hour measurement of equivalent levels $L_{Aeq,T}$ of traffic noise at a given day of working week [4].

Noise annoyance was subjectively assessed using a a modified standardized Noise annoyance questionnaire [5,6]. Information from the 543 respondents (average age 45.3 ± 4.5 years, 73.1% of respondents in the age from 35 to 65 years, 26.9% in the age up to 35 years, 53% females, 81% living in houses more than five years) was obtained by a correspondence form and also by electronic form using a Google questionnaire. University education had 91% of all respondents and 95% of them rated their standard of living as average or above average, 86% of all respondents worked mentally and 15% were retired. About 82 % respondents were not exposed to occupational noise and only 5 % were working on shifts. Approximately 57.6% of respondents remain and spend weekends in their dwellings and 74.9 % devote their time regularly or irregularly to relaxing activities or personal interests.

Residents filled out questionnaires writing a subjective assessment of quality parameters of housing, including the level of annoyance and interference with activities, self-evaluation of their health and lifestyle by using a four grade rating scale. The questionnaire comprised 43 questions divided conceptually into the fields: house and home, traffic noise and housing, traffic noise and sleep, work place and noise, lifestyle and health and the overall level of housing quality.

For statistical processing of data descriptive and bivariate analyses were used (t-test, chi-square test, 2x2 tables) using the software packages EPI Info 7 and SPSS version 25.

RESULTS AND DISCUSSION

Exposure assessment

The questionnaire was supplemented by traffic noise-measurements in towns Bratislava, Martin, Trenčín, Piešťany on noisy facades with distance approximately 50 meters ($L_{Aeq,day}$ = from 57 dB to 72.4 dB, $L_{Aeq,night}$= from 52.5 dB to 61.9 dB) and more than 100 meters from noisy traffic communications or inner-city corridors (Table 1, 2). Outdoor noise levels in Tables 1 and 2 apply to noisy residential building facades within 1.5−2.0 m in front of the window in the living room on the floor level of the overhead floor in accordance with the Slovak legislation [7]. In some cases, outdoor noise measurements were also supplemented with measurements inside of living rooms or bedrooms by the ventilation position of the facade window (Table 3). The corresponding 24-hour road traffic intensity assessments in selected Bratislava sites during working days and evenings in the summer period were 15532 to 46449 vehicles and during the night 1583 to 5116 vehicles (Municipality, Bratislava, 2016), which represents about 8,3 million vehicles per year.

Measurements were carried out by accredited companies and professionally qualified persons with calibrated sound-level technology, in some cases also as final approval measurements of new residential buildings (RB) or after their reconstruction.

Table 1: Equivalent outdoor noise levels $L_{Aeq,T}$ and the indicator L_{den} for 24h measurements on noisy facades (about 50 meters from noisy traffic communication)

Number	Location of RB Bratislava	Floor	$L_{Aeq,T}$ /dB/			Lden /dB/
			T=06h-18h day	*T=18h-22h evening*	*T=22h-06h night*	
1	Gagarinova	7	72.0	68.0	60.3	71.7
2	Račianska	4	72.4	69.3	61.4	72.5
3	Námestie SNP	3	62.4	62.8	59.7	67.0
4	Námestie 1.mája	4	64.8	63.1	61.9	68.9
5	Hodžovo námestie	4	71.0	68.7	64.0	72.7
6	Vajnorská	2-3	68.4	65.0	61.0	69.7
7	Námestie Slobody	5	66.6	65.0	58.5	68.0

Source: Sky-Eco, AZ Acoustic. Legend: RB=Residential Building

Table 2: Equivalent outdoor noise levels $L_{Aeq,T}$ and the indicator L_{den} for 24h measurements on noisy facades (≥ 100 meters from noisy traffic communications)

Number	Loction of RB Bratislava, Trenčín, Martin, Piešťany	Floor	L Aeq,T /dB/			Lden /dB/
			T=06h-18h day	*T=18h-22h evening*	*T=22h-06h night*	
1	BA, Račianska	5	57.4	53.9	49.7	58.5
2	BA,Strojnícka/Mierová	4	59.1	56.4	53.5	61.4
3	BA, Jégeho	5	57.7	54.1	48.5	58.3
4	BA, Lipského	3	60.5	57.8	49.7	60.7
5	MT, Kuzmányho	3	51.8	49.4	42.6	52.6
6	TN, Legionárska	3	53.4	52.3	48.3	56.3
7	PN, A.Hlinka	2	52.1	49.5	41.9	52.6

Source: Sky-Eco, AZ Acoustic, Akustech. Legend: RB=Residential Building, BA=Bratislava, MT=Martin, TN=Trenčín, PN=Piešťany

Table 3: Equivalent indoor-noise levels $L_{Aeq,T}$ in bedrooms facing noisy facades 50 meters from noisy traffic communications for windows in ventilation position or for ventilation slot in the window frame *

Number	Locality of RB Bratislava	Floor	L Aeq.T /dB/		
			T=06h-18h day	*T=18h-22h evening*	*T=22h-06h night*
1	Gagarinova	7	55	51	43
	Gagarinova *		--	30 *	26 *
2	Račianska	24	52	44	37
	Račianska *		--	32 *	25 *
3	Radlinského	4	54	49	46
4	Račianske mýto	4	48	39	35
5	Černyševského-Petržalka	11	48	46	45

* ventilation slot in the window frame

Questionnaire – noise annoyance and sleep disturbance

The inhabitants with bedroom windows facing noisy streets or quiet streets, inhabitants living in the large cities or in the rural area and also at the distance approximately up to 50 meters from noisy streets and more than 100 meters from noisy traffic communications or inner-city corridors represented the exposed and the control group.

Respondents reported the highest annoyance from night noise during the summer period, 76 % of them regularly sleep with their windows open.

Road traffic noise annoys significantly more daily and night activities of respondents in the exposed group (OR=2.66; 95 % CI=1.64−4.31 for falling asleep disturbance). Inhabitants with window orientation into noisy communications are significantly less satisfied with their quality of living (OR=0.35; 95 % CI =0.20-0.61), are less noise-sensitive and report more sleeplessness (OR=2.54; 95 % CI =1.38-4.92).

Inhabitants living in the distance up to 50 meters from noisy streets significantly more awakened by road traffic noise (OR=1.76; 95 % CI=1.04−2.97). Respondents from large cities are closing windows due to noise annoyance as well (OR=2.22; 95 % CI=1.47−3.37) (Table 3).

Falling asleep, night and early morning awakening and closing windows due to annoyance are significantly more frequent in respondents facing the bedroom window to noisy communications (OR=2.66; 95 % CI=1.64−4.31). Inhabitants living in the distance less than 50 meters from noisy facades are significantly more awakened by road traffic noise (OR=1.76; 95 % CI=1.04−2.97). Respondents from large cities use to close windows due to noise annoyance as well (OR=2.22; 95 % CI=1.47−3.37) (Table 3).

The answers of respondents to their potential ability to adapt and to get used to traffic noise during the day and night are shown in Table 4. In the exposed group from large cities respondents are able to adapt to road traffic noise in the night (OR=2.02; 95% CI=1.36−3.01) in comparison to respondents from the rural areas. Inhabitants with bedroom windows orientation into noisy communications are significantly less satisfied with their quality of living, are less noise-sensitive and report more sleeplessness (Table 4).

Preliminary results of our study are compatible with the results of the other studies held in Slovakia and abroad [6, 8, 9]. However, subjective adaptation to noise the other authors did not study in such detail. In the recently published Danish study dealing with multi-storey housing and road traffic and neighbour noise annoyance, the prevalence of being very or slightly annoyed by traffic noise increased between 2013 and 2017. In 2017 36 % of 14,022 respondents living in multi-storey housing reported being very/slightly bothered by neighbour noise and 22 % by traffic noise. Noise annoyance from neighbours was strongly associated with fatigue and sleeping problems [10].

The outcomes of this pilot study support the hypothesis of a subjectively higher level of interference with traffic noise of inhabitants living near urban transport communications (with the traffic of around 20,000 vehicles per day) and over-limit exposure to traffic noise on the noisy facades of residential buildings. The summer nights during working week (between 22h and 06h) are especially risky when noise acts especially troublesome during the time designated

for regeneration and sleep. That was proved by closing the windows of bedrooms especially in the summer night on the side of noisy facades.

Table 3 : Activities interfered by road traffic noise during the night (22h-06h) (n=543)

Activity interfered by road traffic noise	**Exposed and control group of respondents**	**Odds ratio (OR)**	**Confidence interval (95%)**		**P-value**
			Lower limit	Upper limit	
Falling asleep	Bratislava /large cities+rural area	1.36	0.84	2.21	0.206
	Distance from the noisy communication	1.09	0.64	1.83	0.760
	Orientation of bedroom windows	2.66	1.64	4.31	< 0.001
Night and early morning awakening	Bratislava /large cities+rural area	1.71	1.17	2.49	0.005
	Distance from the noisy communication	1.76	1.04	2.97	0.035
	Orientation of bedroom windows	1.90	1.17	3.08	0.009
Closing windows due to annoyance	Bratislava /large cities+rural area	2.22	1.47	3.37	< 0.001
	Distance from the noisy communication	2.66	1.68	4.19	< 0.001
	Orientation of bedroom windows	2.87	1.84	4.36	< 0.001

Table 5: Adaptation to noise and well-being during the day and night (n=543)

Activity	Exposed and control group of respondents	Odds ratio (OR)	Confidence interval (95%)		P-value
			Lower limit	Upper limit	
Adaptation to road traffic noise in the night	Bratislava /large cities+rural area	2.02	1.36	3.01	0.001
	Distance from the noisy road	1.18	0.78	1.78	0.438
	Orientation of bedroom windows	1.16	0.75	1.78	0.507
Satisfaction with quality of living	Orientation of bedroom windows	0.35	0.20	0.61	< 0.001
Subjective noise sensitivity	Orientation of bedroom windows	0.507	0.34	0.75	< 0.001
Sleeplessness	Orientation of bedroom windows	2.54	1.38	4.92	< 0.001

The comparison of selected groups of respondents may be affected by confounding factors, such as relatively small sample size overall and the small sample size of the control groups of respondents, orientation of residential rooms and windows in residential buildings due to noisy communications, floor height, and the subconscious psychological barrier of respondents in the exposed group as property owners resulting from economic interest in their housing.

In the future analysis, we plan to enlarge the sample size, especially in the control groups, and to further evaluate the health and lifestyle of respondents and to suggest precautions and interventional procedures.

There are three possible approaches to protect residents from road traffic noise; the first directed at reducing the noise sources including of application barriers buildings without living, the second at the modification of housing, and the third at reducing the possibility of noise reaching the housing including orientation and distance of the bedroom windows in residential buildings in relation to the major streets and corridors as above in the city planning.

The acoustic comfort in dwellings, the sufficient sound insulation of building structures from internal and external noise is an important issue with a lot of research done in this field. However, acoustic comfort in Slovakia is highly underestimated. Last but not least, it is necessary in the Slovak Republic to apply improving the enforcement to the right to healthy living conditions and the implementation of legislative requirements and measures in the city planning of urban areas.

Conclusions

Our study was aimed at noise exposure assessment and subjective annoyance by traffic noise of inhabitants living in big cities, near urban transport communications and with bedroom windows facing noisy streets. The outcomes support the hypothesis of the subjectively higher level of interference and poorer adaptation to traffic noise of inhabitants living near urban transport communications mainly within less than 100 m distance from busy roads.

The outcomes of this pilot study support the hypothesis about the correlation of traffic noise annoyance and sleep disturbance with bedroom windows orientation and distance from noisy roads as well as the higher level of interference with different day and night activities and the assumption of increased health risk. Respondents from large cities seem to better adapt to road traffic noise in the night and respondents with bedroom windows oriented toward noisy communication are less noise-sensitive.

After completion of the results, we plan to propose interim measures to noisy facades of the apartment buildings as well as intervention procedures in the prevention of adverse effects of traffic noise on health including of application healthy lifestyle principles in the city planning. The health impact of noise from neighbour housing and indoor noise sources should be taken into account as well.

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