Exposure to road traffic noise in new residential buildings

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Summary

According to the results of the LARES study in panel block buildings in three cities of Eastern Europe sponsored by WHO, noise represents a traditional urban problem and noise annoyance was recognized as one of the most prevalent problems affecting residential health and well-being. Health effects were identified also for selected physical and stress-related symptoms, such as hypertension and migraine, which showed significantly increased relative risks.

This paper presents preliminary results of a pilot cross-sectional study focused on subjective traffic noise annoyance, interference with activities; sleep disturbance, adaptation to noise and subjective evaluation of the health state among the residents in selected new apartment houses situated close to major inner city corridors in Slovakian capital Bratislava.

The noisy facades of these buildings have road traffic noise exposure above the limit during the day and the night ($L_{Aeq,day}$ = from 65 dB to 72 dB, $L_{Aeq,night}$= from 52 dB to 60 dB). The equivalent noise levels difference from the noisy and the quiet façade was 7−13 dB, depending on the particular situation. Statistical outcomes of the questionnaire survey on the pilot sample of 176 respondents (average age 41.7 ± 9.3 years, 57% females, living in houses in the average for four years), are presented comparing the exposed (n=132) and the control group of inhabitants with bedrooms windows facing noisy streets or quite streets (n=44).

The outcomes of this pilot study support the hypothesis of subjectively higher level of interference (OR=2.86; 95 % CI=1.27−6.44 for sleep) and poorer adaptation of inhabitants to noise by day and by night (OR=3.20; 95 % CI=1.06−9.63). The assumption of increased subjective health risk (OR=1.45; 95 % CI=0.59−3.55) was not statistically significant.

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.

PACS no. 43.10.e, 43.50.Rq

1. Introduction

According to WHO, excessive noise seriously harms human health and interferes with people's daily activities at school, at work, at home and during leisure time. It can disturb sleep, cause cardiovascular and psychophysiological effects, reduce performance and provoke annoyance responses and changes in social behaviour.

Traffic noise alone is harmful to the health of almost every third person in the WHO European Region. One in five Europeans is regularly exposed to sound levels at night that could significantly damage health [1].

According to the results of the LARES study in panel block buildings in three cities of Eastern Europe sponsored by WHO, noise represents a traditional urban problem and noise annoyance was recognized as one of the most prevalent problems affecting residential health and well-being [2].
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]. According to WHO and environmental burden of disease (EBD) 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].
This also applies to newly built apartment buildings in Slovakia, often built close to the busy urban communications.

This paper presents preliminary results of a pilot cross-sectional study focused on objective assessment of noise, road traffic parameters, air pollution and the subjective traffic noise annoyance. The interference with daily activities; sleep disturbance, adaptation to noise and subjective evaluation of the health state was assessed as well among the residents in selected new apartment houses situated close to major inner city corridors in Slovakian capital Bratislava.

2. Methods

In the pilot cross-sectional study, we assessed the exposed and control groups of inhabitants in Bratislava. The exposed group lived in newly built apartments with windows of bedrooms at noisy facades oriented towards the major inner city transport corridors and the control group in the same newly built apartment buildings with windows of bedrooms oriented to the side facing away the noisy corridors, to the courtyard. We selected newly built or renovated multistage multifunctional high-rise buildings with a residential operation from the second or the third above ground floor located in the wider center of Bratislava at a distance of about 50 meters from the main inner city roads, which are significantly exposed to traffic noise from the road or urban rail transport (trams). The survey was conducted in agreement with the administrators of the apartment buildings on the street Gagarinova (residential complex “Perla Ruzinova”) Racianska (residential complex “Manhattan”) and Racianske Myto Square, Radlinskeho and Cernysevskeho Street.

Objective measurements of noise in the external facades of selected residential buildings (RB) oriented to the nearest major transport corridors were performed as a continuous 24 hour measurement of equivalent levels L_{Aeq} of traffic noise at a given day of working week [4,5]. At the same time the measurements and prediction of indoor noise in the given living room, were performed, while ensuring a minimum-ventilation through the window in the position of ventilation or using so-called ventilation slots in the window frame of the projection ventilation system in the apartment [4,5].

Noise annoyance of residents was assessed subjectively using a modified standardized Noise annoyance questionnaire [6,7]. Information from respondents was obtained by correspondence. Residents filled out questionnaires at home 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, odds ratio and 95 % CI) using the software package SPSS version 25, EPI Info 7 and Microsoft Excel, 2016.

3. Results

Exposure assessment

The noisy facades of these new residential buildings have road traffic noise exposure above the limit during the day and the night ($L_{Aeq,day}$ = from 65 dB to 72 dB, $L_{Aeq,night}$= from 52 dB to 60 dB) (Table I, II). The equivalent noise levels difference from the noisy and the quiet façade was 7−13 dB, depending on the particular

situation. On these facades the barrier effect or so called soundproof barrier effect of the building itself or the surrounding buildings occur.

Table I. Traffic noise levels in the noisy facades of RB (residential buildings) – outdoor noise

Locality/street	*OF*	$L_{Aeq,T,OUT}$ *(dB)*		
		06-18 h Day	*18-22 h Evening*	*22-06 h Night*
Gagarinova	7	72	68	60
Cernysevskeho	11	65	63	62
Racianska	24	69	61	54
Racianske Myto	4	65	56	52
Radlinskeho	4	71	66	63

Legend: OF=overhead floor

Table II. Traffic noise levels in the noisy facades of RB (residential building) - indoor noise, windows in ventilation position or with ventilation slots (*)

Locality/street	*OF*	$L_{Aeq,T,OUT}$ *(dB)*		
		06-18 h Day	*18-22 h Evening*	*22-06 h Night*
Gagarinova	7	55	51	43
Gagarinova*	7	–	30*	26*
Cernysevskeho	11	48	46	45
Racianska	24	52	44	37
Racianska*	24	–	32*	25*
Racianske Myto	4	48	39	35
Radlinskeho	4	54	49	46

Legend: OF=overhead floor, *ventilation slot in the window frame

Table III. Number of vehicles on Gagarinova street in the summer period (source: Bratislava Magistrate, 2016)

Street	*Year*	*Time interval*		
		06-18 h Day	*18-22 h Evening*	*22-06 h Night*
Gagarinova	2011	18,675	3,481	1,451
Gagarinova	2013	18,603	3,602	1,443
Gagarinova	2015	18,248	3,584	1,506

Intensity of traffic flows related to the main city roads and trends in recent years, according to data from Bratislava Municipality collected in selected transport hubs, or selected city crossroads, show relatively long-term stability in the range +/- 5%. Table III shows the situation in Gagarinova Street.

Air pollution was assessed by Slovak Hydrometeorological Institute in the measurement station nearby (Trnavske Myto) (Table IV)

The station Bratislava - Trnavske Myto is situated near the large busy crossroads, Sancova and Trnavska street - Krizna and Vajnorska street. It represents a position with extreme high road transport emissions.

The main contributors to air pollution represent the chemical industry, energetics and car traffic. Secondary suspended particles, the level of which depends upon meteorological factors, land use, agricultural activities and characteristics of surface, are significant source of air pollution by particular matter.

In 2015, the annual limit value was exceeded at the monitoring station Bratislava - Trnavske Myto (49 μg. m^{-3}) (Table IV). In 2015, the limit value of daily mean PM_{10} concentrations for the protection of human health has been exceeded at the station Bratislava-Trnavske Myto 40 times. The average annual concentration of benzo(a)pyrene at AMS Bratislava-Trnavske Myto did not exceed the target value [8].

Table IV Assessment of air quality according to limit values for protection of human health in agglomeration Bratislava − 2015

Monitoring station	*Pollutant* $\mu g.m^{-3}$				
	NO_2 *1 year*	PM_{10} *24 h*	PM_{10} *1 year*	*CO*	*Ben-zene*
Trnavske Myto	**49**	40	32	2,155	1.6
Limit	**40**	50	40	10,000	5

Source: Slovak Hydrometeorological Institute, 2017 [8]

Outcome

Statistical outcomes of the questionnaire survey on

the pilot sample of 176 respondents (average age 41.7 ± 9.3 years, 57% females, living in houses in the average for four years), are presented comparing the exposed (n=132) and the control group of inhabitants with bedrooms windows facing noisy streets or quite streets (n=44).

In the exposed group there were 56% females and 44% males. The mean age was 41.13 years. In the control group there were 59% females and 41% males and the mean age was 43.57 years. The differences in sex and age were not significant (p= 0.7 and p=0.3). The significant difference, however, was in the floor height for the exposed group, that live on the higher floors (p = 0.003). More than 40% of them live from the 8th floor up comparing to the 16% percent of respondents in the control group.

The outcomes of this pilot study support the hypothesis of subjectively higher level of interference with day and night activities in flats (OR=2.86; 95 % CI=1.27−6.44 for sleep; OR=5.96; 95 % CI=2.36−15.05 for falling asleep) and poorer adaptation of inhabitants to noise by day (OR=2.88; 95 % CI=0.82−10.12) and by night (OR=3.20; 95 % CI=1.06−9.63).

Table V. The analysis of traffic noise annoyance in the exposed and the control group (odds ratio)

Activities of respondents in flats	*OR (odds ratio)*	*Confidence interval 95 %*	*P value*
Listening to radio, TV, talk and telephone (day)	5.71	2.72−11.99	<0.0001
Reading, mental work (day)	3.50	1.60 −7.67	0.001
Adaptation to noise (day)	2.88	0.82−10.12	0.009
Falling asleep	5.96	2.36−15.05	<0.0001
Sleep	2.86	1.27−6.44	0.009
Adaptation to noise (night)	3.20	1.06−9.63	0.031

Respondents subjectively assessed their overall health in 62% as good or more than good and age-appropriate in 32% of cases. Fairly bad or very bad health stated respondents only in 6% of cases. Approximately 53% of respondents remain and spend weekends in their dwellings and 84% devote their time regularly or irregularly to relaxing activities or personal interests. The subjective assessment of health status was not significantly different (p = 0.8).between the exposed and the control group. The assumption of increased subjective health risk (OR=1.45; 95 % CI=0.59−3.55) was not statistically significant as well as the other non-auditory health effects (headache, high blood pressure, intake of hypnotics and overweight) (table VI).

Table VI. The analysis of non-auditory effects of road traffic noise in the exposed and the control group (odds ratio)

Subjective evaluation of respondents' health status	*OR (odds ratio)*	*Confidence interval 95 %*	*P value*
Headache	1.93	0.65 – 5.74	0.23
Intake of medicaments - hypnotics	1.68	0.46 – 6.12	0.43
High blood pressure	1.38	0.55−3.45	0.50
Overweight	0.76	0.28−2.02	0.58
Total health status	1.45	0.59−3.55	0.41

4. Discussion

Statistical outcomes of the questionnaire survey on the pilot sample of 176 respondents are presented comparing the exposed and control group of inhabitants with bedrooms windows facing noisy streets or quite streets. Road traffic noise annoys significantly more daily and night activities of respondents in the exposed group (OR=2.86; 95 % CI=1.27−6.44 for sleep disturbance), who are unable to adapt to it neither by day nor by night.

Preliminary results of our study are compatible with the results of the other studies held in Slovakia and abroad [9,10,11,12]. However, the subjective adaptation to noise they did not follow in such detail. The other studies in Slovakia did not consider air pollution in the observed area as well.

The outcomes of this pilot study support the hypothesis of subjectively higher level of interference and poorer adaptation to traffic noise of inhabitants living near urban transport communications (with a 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. It was proved by closing the windows of bedrooms especially in the summer night on the side of noisy facades.

Concerning air pollution, the one-year limit in 2015 for NO_2 has been slightly exceeded in the monitoring station Trnavske Myto, near the street Racianska, Racianske Myto. The limit value of daily mean PM_{10} concentrations has been exceeded for 40 times. Current knowledge suggests that noise and air pollution may affect the cardiovascular system by different mechanisms. Transport systems (road traffic in particular) generate both noise and air pollution (e.g. PM, NO_x, HC, CO, SO_2). Thus, it is possible that combined exposure to these transport related stressors may interact and increase their single effects on cardiovascular risk synergistically [13, 14, 15]. In our sample the effect on cardiovascular system and overall health state was not shown.

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 group 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 group, 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 by manufacturers (electro-mobiles can be sometimes a good example) or by decreasing of speed of cars in critical city areas, the second at the modification of housing orientation from distance from main city roads point of view, and the third at reducing the possibility of noise reaching the housing by improving of ventilation systems and ventilation slots of flats [3].

5. Conclusion

Our study was aimed at noise exposure assessment and subjective annoyance by traffic noise of inhabitants living near urban transport communications of the Slovakian capital Bratislava. The outcomes of this pilot study support the hypothesis of subjectively higher level of interference and poorer adaptation of inhabitants to noise and the assumption of increased health risk. 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.

The health impact of noise from neighbor housing surroundings and indoor noise sources should be taken into account as well.

Acknowledgement

The research was partially supported by grant Y.A.B.S. (Youth and Parents Behavioral Survey in Slovakia) O-15-101-/0001-00 and by the ESF-OPV project „MPH study programme development at Comenius University in Bratislava in English language (Master of Public Health).“ ITMS code of the project: 261402300093.

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