14th ICBEN 2023 18 - 22 JUNE BELGRADE

14th ICBEN Congress on Noise as a Public Health Problem

The impact of the COVID-19 pandemic on road traffic noise annoyance trends

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ABSTRACT

Environmental noise, particularly road traffic noise, has been considered one of the most widespread environmental pollutants, but the COVID-19 pandemic significantly altered urban environments. The study's goal is to assess noise annoyance trends over time in Bratislava's long-term monitored neighborhoods at 10, 20, and 30-year intervals including the situation during the global COVID-19 pandemic. We used the validated methodology for the subjective assessment of noise annoyance and psychosocial well-being in young and healthy individuals and the method of objectification by direct measurement of sound levels. The respondents (n=3,197), university students, who lived in the exposed and control locations represented a homogeneous sample of the population. The sharp increase in traffic noise burden in the exposed area was found at the first 10-year interval (1989–1999) (L_{Aeq}=67.5 dB). A slight decrease occurred in 2019 up to L_{Aeq}=63.9 dB and during the lockdown, it dropped to L_{Aeq} =62.5 dB. We observed a more significant decrease at the control site, where the noise level dropped to L_{Aeq} = 50.2 dB in 2019 and L_{Aeq} =46 dB in 2020. A sharp increase in road traffic noise annoyance was observed in the first 10-year interval (OR_{MH}=2.56 (95 % CI=1.93–3.42) vs 6.01 (95% CI=4.97–7.95) with a decreasing trend up to 2020-2021 (OR_{MH}=4.37 (95% CI=2.98–6.40) and (OR_{MH}=3.26 (95% CI=2.19–4.90) in 2023. Despite a slightly declining trend, road traffic noise annoyance is an important issue. The experience generated by the pandemic offers data for the development of healthy urban transport and the necessity of applying preventive procedures to reduce traffic noise.

Keywords: Road traffic noise, COVID-19 pandemic, Noise annoyance, Trends

INTRODUCTION

For a long time, the negative effects of noise on human health and development were underestimated. This could be because, unlike other hazardous substances in the workplace or environment, noise endangers human health in an indirect manner. However, noise is ubiquitous in daily life and can have both auditory and non-auditory health consequences. [1, 2, 3]

Environmental noise was once referred to as the "forgotten pollutant," but it is now acknowledged as a problem for the environment and public health that must be resolved in contemporary society. [2, 3, 4]

Road, rail, and air traffic, as well as construction sites, are significant sources of environmental noise exposure. Other sources of noise exposure include wind turbines and leisure activities such as listening to loud music or other audio content, as well as participation in e-sports (video and computer game competitions). [2, 3, 5]

Excessive noise can cause annoyance; however, research shows that it increases the risk of IHD and hypertension, as well as sleep disturbance, hearing impairment, tinnitus, and cognitive impairment, with growing evidence for other health effects such as adverse birth outcomes and mental health problems. [2, 3, 4, 5]

Around 56 million people (54%) in the European Union reside in cities with populations of more than 250 000, and they are exposed to road traffic noise levels that are higher than the average L_{DEN} (day-evening-night) 55 dB per year, which is considered health-threatening. [2,3]

According to the World Health Organization (WHO), at least 1 million healthy life years (disability-adjusted life-years) are lost each year in high-income European countries (population of roughly 340 million people) due to ambient noise. [2,3]

Sleep disturbance and annoyance by environmental noise (especially from road traffic) are the most serious environmental burden of disease, representing 903,000 and 654,000 disability-adjusted life-years (DALYs). [1,2]

In Slovakia, the rapid increase in traffic density associated with the country's economic transformation since 1989 has resulted in new environmental noise problems, particularly road traffic noise.

The study aims to evaluate noise annoyance trends over time in long-term monitored neighborhoods in Bratislava at intervals of 10, 20, and 30 years, taking into account the conditions during the global COVID-19 pandemic.

MATERIALS AND METHODS

Study Design

This study analyzes the changes in noise load over time for a number of population groups in

the Bratislava area (10, 20, and 30 years). Along with the general level of discomfort caused by various environmental noise sources, we also monitor disorder and interference with various daytime, evening, and nighttime activities.

The subjective evaluation of "annoyance" and psychosocial well-being, as well as the objectification of noise levels by direct measurement method utilizing a sound level analyzer with a module for frequency analysis, were done using the validated methodology. Bivariate and stratified analyses have established the basis for statistical and epidemiological analyses.

Exposure

For a long time, we have used Brüel-Kjaer measuring techniques to monitor equivalent noise levels (L_{Aeq}) at the exposed and control sites in Bratislava at various time intervals.[6]
During the regular working week in spring and autumn, two separate measurements were taken in both the exposed and control areas. During the day (6.00-12.00), afternoon (12.00-18.00), evening (18.00-22.00), and night (22.00-6.00), all measurements were taken in accordance with the applicable legislation. Each measurement was taken at a 15-minute interval. Measuring stations were placed two meters away from the building facades. The average equivalent noise levels ($L_{Aeq,24h}$) for exposed and control areas were calculated and compared.

Based on our measurements and strategic noise maps L_{DEN} (day-evening-night noise indicator), we determined the exposed location to be the place of a major university dormitory.[7] Throughout the day, this location is highly exposed to traffic noise from both road and rail traffic (trams). The control site is located in another university dormitory in a quiet pedestrian zone. The goal of these measurements and estimations was to reasonably categorize the subjects based on levels of noise exposure for the purposes of epidemiological research.

Subjective response - questionnaire

A validated noise annoyance questionnaire administered in person and modified over 10, 20, and 30 years was used to assess the subjective response. [6,7] It included questions on noise annoyance from various sources, interference with various activities, and sleep disturbance, in addition to the demographic (age, gender, education, occupation, nationality) and behavioral (smoking, coffee, and alcohol consumption) and housing characteristics (building construction and type of residence). The questionnaire also included window orientation to quiet or noisy streets, flat location, and length of stay in a dormitory (at least four years in the same place).

For the years 1989 through 1999, we used a three-graded scale (Not at all annoys; Moderately annoys; Annoys) and for the years 2000 through 2022, we used a five-grade verbal scale (Not at all; Slightly; Moderately; Very; Extremely), developed and advised by experts from the ICBEN (The International Commission on the Biological Effects of Noise). [8]

However, for statistical purposes, the results had to be dichotomized (Not at all+Slightly; Moderately+Very+Extremely) or trichotomized (Not at all+Slightly; Moderately,

Very+Extremely).

We also focused on the situation during the global COVID-19 pandemic. The questionnaire was administered in person, with the exception of the COVID-19 period. At that time the questionnaire was administered online using google forms application.

Samples

The source population was made up of Comenius University medical students. The respondents comprised a homogenous sample of young, healthy people with similar ages, educational backgrounds, and lifestyles. The response rate was 90%.

Only the city, Bratislava-based students were qualified to take part in the study. Table 1 lists the number of responders who resided in the exposed and control areas 10, 20, 30, and during the COVID-19 pandemic (2020-2021) and in the year 2022, just after the COVID-19 pandemic. There were no significant differences between the exposed and control group of respondents in terms of age, gender, education, health, or lifestyle characteristics. They differed in their residence location in relation to noise exposure (quiet, noisy area), flat position in the floor height, windows orientation, satisfaction with flat surroundings and noise annoyance.

Table 1. Number of respondents during the years 1989 – 2023 (n = 3,197)

Year	Exposed group (n/%)	Control group (n/%)	Total
1989	166 /31	374/69	540
1999	374/44	483/56	857
2009	280/ 42	379/58	659
2019	87/ 31	195/69	282
2020-2021	78/37	132/63	210
2022-2023	199/37	340/63	539
Total	**1 294/40**	**1 903/60**	**3 197**

Statistical analysis

To calculate community noise annoyance risks from various sources and the risks of interference with road traffic noise, bivariate and stratified analyses (presented as crude odds ratios, and Mantel-Haenszel weighted odds ratios) were applied. When the variables (Road traffic noise interference and annoyance) were trichotomized (Not at all+Slightly; Moderately, Very+Extremely), the Mantel-Haenszel weighted odds ratio was used in stratification analysis.

The risks were followed at time intervals of 10, 20, and 30 years and the time trends were assessed. Major analytical tools were Epi Info™, different versions during decades, the latest version EPI-INFO 7.2.5.21, and IBM SPSS Statistics 25.0 (International Business Machines Corp., New Orchard Road, Armonk, NY, USA).

RESULTS AND DISCUSSION

Based on the results of measurements of noise exposure in the exposed and control sites, we found a continuous increase in traffic noise burden in the exposed area at intervals of 10, 15, and 20 years beyond the health risk zone of L_{Aeq} =60 dB (Figure 1). From the evaluation of noise levels during the day, we can assume that the highest values were recorded in the period from 1999 to 2009 when they reached L_{Aeq} = 67.5 dB (Fig. 1).

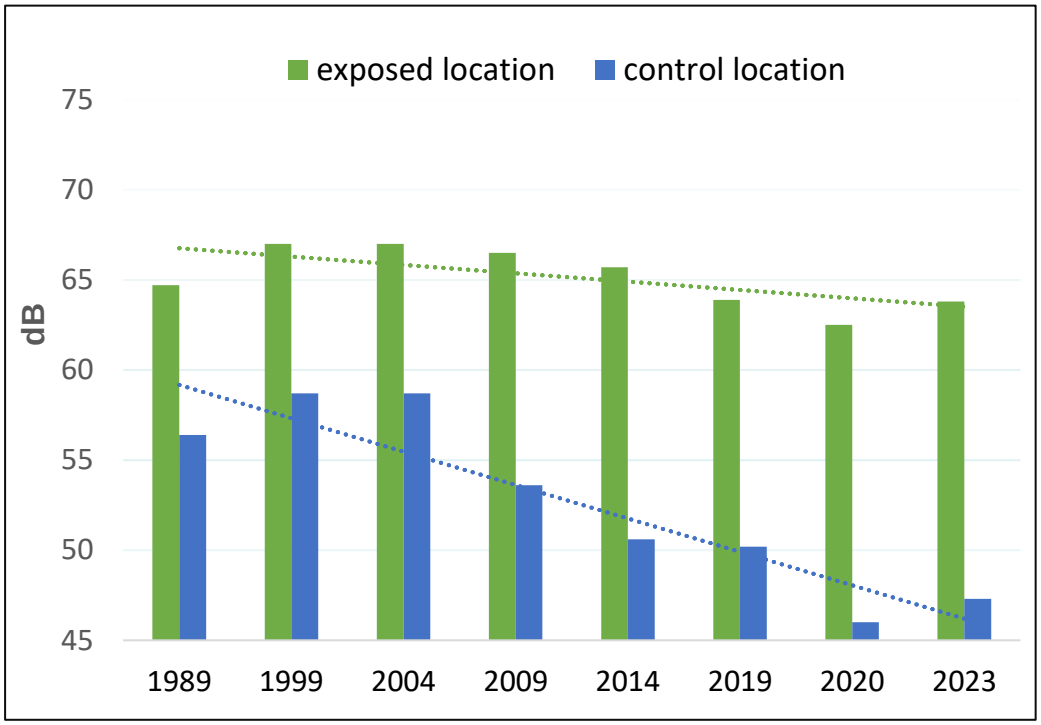

Figure 1 The development of noise levels in the observed areas during 1989-2023

According to WHO, the negative effects of noise on health begin to manifest at values above L_{Aeq} = 50 dB (annoyance, short-term communication disorders, negative effects on mental work).[2] For noise levels greater than 60 dB, the myocardial infarction risk increases continuously, with relative risks (odds ratios) ranging from 1.1 to 1.5.[9] Thus, the measured noise levels exceeded the permissible levels according to the national Decree No. 549/2007 Coll. as amended and can cause serious noise annoyance and sleep disturbance, and later psychosomatic disorders.[10] A slight decrease occurs after 2014 when the measured values fell to L_{Aeq} = 65.7 dB and in 2019 to L_{Aeq} = 63.9 dB. In 2020, during lockdown due to the COVID-19 pandemic, they dropped to L_{Aeq} =62.5 dB. However, they still reach higher values than allowed in residential areas and around school facilities. We observed a more significant decrease in environmental noise levels at the control site, where the noise level from L_{Aeq} =58.7 dB in 1999 dropped to L_{Aeq} = 50.2 dB in 2019 and L_{Aeq} =46 dB in 2020 (Fig. 1). The difference between the exposed and control locations was significant in each monitoring period ($p < 0.001$). In 2023, after the COVID-19 pandemic, the measured values increased in

the exposed and in the control location by 1 dB (Fig. 1).
The most disturbing environmental noise source in the exposed location was road traffic noise, followed by noise from entertainment facilities. Subjectively, we observed a sharp increase in value risk causing road traffic noise annoyance over 10 years (OR_{MH}=2.56 (95 % CI=1.93–3.42) in 1989 and 6.01 (95 % CI=4.97–7.95) in 1999) (Table 2). In addition to road traffic noise, we observed an increase in noise annoyance from railways – trams (OR_{MH}= 3.05 (95 % CI=1.93–4.82 in 2019). The important issue has been the noise annoyance from the entertainment facilities (OR_{MH}=3.45 (95 % CI=2.32–5.13 in 2019) and (OR_{MH}=4.31 (95 % CI=3.25–5.72 in 2023), and from the neighborhood (OR_{MH}= 2.81 (95 % CI=2.12–3.74 in 2023) (Table 2).

Table 2. Environmental noise annoyance risks from different sources (1989 – 2022)

Noise annoyance risks	**Source of noise** OR_{MH} (95 % CI)			
Year	**Road traffic**	**Neighborhood**	**Entertainment facilities**	**Railway**
1989	2.56 (1.93–3.42)***	1.71 (1.29–2.27)***	1.51 (0.90–2.52)	0.56 (0.31–0.98)*
1999	6.01 (4.97–7.95)***	2.43 (1.99–3.03)***	3.90 (3.19–5.46) ***	2.06 (1.58–2.71) **
2009	5.41 (4.28–7.25)***	2.48 (1.99–3.19)***	2.27 (1.76–2.98)***	1.41 (1.04–1.92) *
2019	5.41 (3.56–8.36) ***	1.69 (1.16–2.47) **	3.45 (2.32–5.13) ***	3.05 (1.93–4.82) ***
2020-2021	4.37 (2.98–6.40)***	1.74 (1.24 – 2.44) **	2.89 (1.99–4.21) ***	1.48 (0.99–2.21)*
2023	3.26 (2.19–4.90) ***	2.81 (2.12–3.74) ***	4.31 (3.25–5.72) ***	2.88 (2.16–3.84) ***

Legend: *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$ CI = confidence interval;
OR_{MH} = Mantel-Haenszel odds ratio

In our study, during and after the COVID-19 pandemic the risks of road traffic noise annoyance decreased. Noise levels in the exposed location dropped by 2 dB and in the control location by 5 dB and increased by 1 dB during the year 2023 after the pandemic. However, an important issue after the COVID-19 pandemic has been the noise from entertainment facilities and neighborhoods, possibly related to the decrease in noise annoyance risk after the COVID-19 pandemic.

The German researchers analyzed the effect of lockdown due to the COVID-19 pandemic on noise levels in Bochum (365,000 inhabitants), similar to Bratislava, located in the densely populated and highly populated city trafficked metropolitan Ruhr Area. They observed a significant reduction in levels in all territories, but the weakest decrease of 3.9 dB from 68.4 dB to 64.5 was found on the main street, compared to the strongest reduction in the formerly quite green urban area.[11] In the French study a significant decrease in sound levels was observed at all the monitoring stations during lockdown. Reductions from 4 dB to 6 dB (L_{den})

were observed for monitoring stations with highly dominant road traffic noise. In addition to the effect noted in terms of sound levels, the structure of the city's soundscape has been significantly changed, and the order of sound sources reversed. Deliveries, stores, terraces, conversations, and other sounds associated with human activity which were before hidden by the predominance of transport noise and other sounds were gradually fading, making space for sounds that were already present but were still barely audible.[12]

The study by Kumar et al., 2022 showed a noticeable increase in noise levels in the school site, in Guildford, UK, after the reopening of schools after COVID-19. It was likely that the elevated noise exposure was due to an increase in road vehicles after loosening the restrictions. As lockdown eased, noise levels increased by up to 3 dB throughout the week, suggesting the potential for greater noise disturbance at weekends than pre-pandemic[13].

In our long-time monitoring study, we observed the highest increase in road traffic noise annoyance during the years 1989 and 1999 which could be attributed to the period of political and socio-economic transformation and the changes in traffic management in our country. Then road traffic noise annoyance risks showed decreasing trend up to 2020-2021 (OR_{MH}=4.37 (95% CI=2.98–6.40) and (OR_{MH}=3.26 (95% CI=2.19–4.90) in 2023. Despite a slightly declining trend, road traffic noise annoyance is an important issue. The experience generated by the pandemic offers data for the development of healthy urban transport and the necessity of applying preventive procedures to reduce traffic noise.

CONCLUSION

The study examined the relationship between environmental noise and noise annoyance across a 30-year period, particularly emphasizing the situation in the defined locations during the global COVID-19 pandemic. The first 10-year period showed a significant increase in road traffic noise annoyance. The substantial increase during 1989 and 1999 may have been due to our country's political and socioeconomic development and changes in traffic management. There was also an increase in annoyance from entertainment facilities. Despite a minor decline, road traffic noise annoyance remains a significant issue, and preventive actions to decrease such exposure in residential areas are required. Our study's findings point to the necessity for preventive actions to reduce environmental noise exposure in residential areas, as well as further research in this area.

Acknowledgments

This work was supported in part by the grant KEGA 015UK-4/2022, Innovation of education in the field of health protection and promotion with an emphasis on e-learning and implementation of multimedia technologies

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