Environmental noise and annoyance in adults: Research in Central, Eastern and South-Eastern Europe and Newly Independent States

Jurgita Lekaviciute, Lubica Argalasova-Sobotova

European Commission, Joint Research Centre, Institute for Health and Consumer Protection, Chemical Assessment and Testing Unit, Ispra (VA), Italy, 1Institute of Hygiene, Faculty of Medicine, Comenius University, Bratislava, Slovakia

Abstract
Research work on the adverse effects of noise on annoyance in adults is well documented in Western Europe, but there is a knowledge gap concerning this type of research in Central and Eastern Europe (CEE), South-East Europe (SEE), and Newly Independent States (NIS). The objective of this review was to present findings and to propose future research directions for the studies on the effects of environmental noise on annoyance in adults conducted in these countries. After systematic search in accessible databases, scientific journals, conference proceedings, international and national reports in English and other languages, the authors identified 29 papers to be included to this review: 24 papers related to annoyance due to road traffic noise and 5 papers related to annoyance from other noise sources. In most of the identified studies, a cross-sectional design prevailed and the evaluations were mainly performed subjectively. The lack of recent annoyance studies related to railway and aircraft traffic noise was identified. Only two studies from NIS countries used noise exposure data for the evaluation of population annoyance according to the European Environmental Noise Directive (END). Capacity building in CEE, SEE, and NIS countries is necessary to acquire the “know-how” on how to implement and use the different scenarios for evaluating population annoyance by environmental noise, depending on the availability and suitability of noise exposure data. Particular attention should be given to the possible use of END noise exposure data, where applicable.

Keywords: Annoyance, environmental noise, environmental noise directive, review, road traffic noise

Introduction
Modern society moves toward the cities and develops into a “loud” society, implying that people are surrounded by noise for nearly 24 h a day, and are affected not only by traffic or aircraft noise, but also by neighborhood or leisure noise. A pilot project on the environmental burden of disease in Europe showed that 3-7% of the World Health Organization (WHO) discounted age-weighted burden of disease was associated with nine selected environmental stressors in six participating countries. Among these nine stressors, air pollution had the highest public health impact, followed by second-hand smoke and traffic noise.[1]

Annoyance is the most prominent adverse effect of noise associated with exposure to intermediate and high noise levels.[2] People annoyed by noise may experience a variety of negative responses, such as anger, disappointment, dissatisfaction, withdrawal, helplessness, depression, anxiety, distraction, agitation, or exhaustion.[3,4] In more, stress-related psychosocial symptoms such as tiredness, stomach discomfort, and stress have been found to be associated with noise exposure as well as with noise annoyance.[3,6] Annoyance is typically measured by self-reports to a wide range of questions using response scales with a varying number of response categories. The content of the reaction measure ranges from quality of life impairment, general annoyance, and specific activity interferences, to overall indicators of being affected by noise. Two to eleven scale points are usually employed.[3] However, the efforts have been made by the International Commission on Biological Effects of Noise (ICBEN) and the International Organization for Standardization to standardize the questions asking for the degree of annoyance, and to introduce an 11-point numerical scale and a 5-point semantic scale.[7] Annoyance by noise may be modified by the attitudes toward the sources of sound and by personal characteristics
such as noise sensitivity.\[9\] Human perception of noise has changed over time and noise sensitivity is often found to have the largest modifying impact on noise annoyance. The size of this effect is equivalent to that caused by a 10 dB (A) increase in noise exposure.\[10\] Other modifying factors such as noisy neighborhood or having access to a silent side of the dwelling also play an important role in annoyance evaluation.\[2,9\] But as noise annoyance is a subjective indicator of exposure, the results must be evaluated with caution, regarding recall bias.\[10\] This implies a need for more objective measurements.

European Environmental Noise Directive (END) 2002/49/EC recommends evaluating environmental noise exposure on the basis of estimated noise annoyance and proposes the use of day-evening-night equivalent sound level \(L_{den}\) as an acoustic indicator.\[11\] The results of the first round of noise mapping suggested that around 40 million people across the European Union (EU) are exposed to noise above 50 decibels (dB) from roads within agglomerations during the night. More than 25 million people are exposed to noise at the same level from major roads outside agglomerations. These numbers are expected to be revised upward as more noise maps are received and/or assessed.\[12\] EU Member States have already adopted END and are under the second round of strategic noise mapping. They have already started to use the gathered noise exposure data for health studies, whereas the other Central and Eastern European countries, non-EU members, are under the process of harmonization of environmental noise-related legislation. Despite this, they continue performing research work for evaluating environmental noise effects on health. Only a part of these research results are published in English and are accessible to the international scientific society, but most of studies remain unknown, as they are published in other languages.

The aim of this review was to present the findings of the studies on the effects of environmental noise on annoyance in adults conducted in South-East Europe (SEE), Central and Eastern Europe (CEE), and Newly Independent States (NIS), and to propose the directions for future research in this area.

Methods

This review includes scientific papers on environmental noise and related annoyance in adults. The research period is from 1969 to 2010. This review comprises not only papers published in peer-reviewed journals, but also articles from local journals to fill the “white gaps” on the map of noise reviews. Therefore, authors reviewed the scientific journals, conference proceedings, and local reports published in national languages as well. The originality of this review lies not only in the fact that we searched for and included the studies published in other European languages than English, but also we included studies of the countries which no longer exist in the same political and governmental systems (former Easter Germany, former Union of Soviet Socialist Republics [USSR], former Czechoslovakia, former Yugoslavia). We performed the literature search of all accessible medical and other databases (PubMed, Embase, Scopus, BioMed Central, Web of Science, Toxline, Scientia, Science Direct, etc.) using the terms “environmental noise; community noise; road traffic noise; transportation noise; noise sources; adults; noise annoyance” as key words and country denomination (in alphabetical order: Armenia, Azerbaijan, Belarus, Bulgaria, Bosnia and Herzegovina, Croatia, Czech Republic, former Czechoslovakia, Georgia, German Democratic Republic [1965-1990], Hungary, Kazakhstan, Lithuania, the Former Yugoslav Republic of Macedonia, Moldova, Montenegro, Poland, Romania, Russian federation, Serbia, Slovakia, Slovenia, former Yugoslavia, Ukraine, former USSR). In total, 29 papers were identified by literature search. The identified studies with their characteristics are listed in two tables - in the chronological order by year of issue and by alphabetical listing of author’s last name. In the first table, we outlined all the studies related to road traffic noise annoyance, whereas in the second table, we summarized the studies related to noise annoyance from other sources. The tables present the following characteristics of the studies: Location, country, town, and reference (town and country where the study was carried out, the first author and year of publication), aim, and type of the study, sample size, type of exposure assessment (objective or subjective), control variables (covariates), outcome (objective or subjective) and findings. The tables are presented in the special format, which was compiled with the help of the tables from the previous reviews related to noise and health.\[13\]

Results and Discussion

The review comprises 24 papers related to road traffic noise annoyance [Table 1]. Most of the identified papers are from Serbia (four studies), Poland (four studies), and Slovakia (four studies). Two papers from each of the countries such as former Eastern Germany, Czech Republic and Slovenia, and one paper-from Lithuania, the Former Yugoslav Republic of Macedonia, Romania, and former USSR (Russia) are also included. Finally, two more studies are included where one of co-authors has originated from or part of the research work was carried out in one or several of CEE, SEE, or NIS countries.

Our review also contains five studies exploring other noise sources (aircraft, railway or low frequency noise) and annoyance [Table 2]; two of them come from the former USSR and three from Poland.

Noise annoyance from road traffic in urban population

The earliest identified experimental study, which was looking at acoustic analyzer functions, subjective and integral reactions in human subjects, was published in former USSR by Suvorov et al., in 1986.\[14\] We identified two studies on
Table 1: Studies on road traffic noise annoyance in adults in Central and Eastern Europe, South-East Europe, and Newly Independent States

| Location, country, town (reference) | Aim | Type of study | Sample | Exposure assessment | Covariates | Outcome | Findings |
|------------------------------------|-----|---------------|--------|---------------------|------------|---------|---------|
| Moscow, former USSR (Sušorov et al., 1986) | To study acoustic analyzer functions, subjective, and integral reactions in human subjects | Experimental study | Human volunteers | (O) Exposure to inconstant and constant noise with various time characteristics at similar equivalent levels 90-95 dB(A) (S) Subjective evaluation of different types of noise | 1-comparison of exposure to constant and inconstant noise | (O) Clinical and laboratory examination of acoustic analyzer and integral body reactions, BP, R-R interval | The acoustic analyzer reacts to a greater extent to the noise load intensity, subjective and integral reactions reflected the informative significance of noise exposures, inconstant and constant noise with frequency of impulse investigation 30 Hz were similar | |
| Residential areas, city of Erfurt, former Eastern Germany (Schulze et al., 1990, Wölke et al., 1990) | To compare health status of noise-annoyed and not annoyed subjects | Cross-sectional study | Two homogenous samples, 350 adult citizens, 20-75 years with different noise exposure | (O) Equivalent noise levels 72–75 dB (A) in exposed area, 64-67 in control area during day (S) Written and personal interview on noise annoyance and health status | 1-noise exposed versus non-exposed subjects | (S) Sociological self-report study on noise annoyance and self-reported health status | Noise-annoyed subjects reported worse health status, sleeping disorders, higher intake of hypnotics | |
| Bratislava agglomeration, Slovakia (Ághová et al., 1992) | To prepare Bratislava noise maps and to assess noise annoyance | Cross-sectional study | Sample of 764 adult inhabitants, 40% male, 60% female, mostly 20-40 years | (O) Mean equivalent 24 h noise levels in 257 measuring stations (S) Annoyance | 0=no control | (S) Self-reported noise annoyance on three grade scale | 68% measuring stations exceeded L_{eq} 65 dB(A), noise annoyance in 49.6% exposed to >50 dB(A) | |
| Gothenburg, Sweden, first author of publication is from Serbia (Belojević et al., 1992) | To investigate the importance of noise sensitivity in mediating the effects of noise on mental performance | Laboratory experiment | 45 students: 23 males and 22 females, 18-32 years | (O) 3 conditions, high noisy condition L_{eq}=75 dB(A), moderate L_{eq}=55 dB(A), quiet L_{eq}=30 dB(A) (S) Questionnaire: Noise sensitivity, personality traits, annoyance; cognitive tasks (memory, arithmetic) | 1=noise tolerant versus noise moderate versus noise sensitive subjects | (S) Mental performance in relation to noise exposure and noise sensitivity level | Subjects with high noise sensitivity showed poorer performance in deeper mental processing in noisy conditions. Accuracy of performance was positively related to extraversion, negatively related to noise annoyance, attitude towards noise and neuroticism | |
| Residential areas, city of Erfurt, former Eastern Germany (Schulze and Grossman, 1992; Schulze, 1994) | To assess noise annoyance in the random sample of Erfurt citizens | Cross-sectional study | 1,000 adult citizens, 20-75 years, representative sample | (O) Equivalent noise levels, maximal noise levels, L_{eq}=57 dB(AI) as limit value (S) Written and personal interview on noise annoyance | 0=no control, sociological study | (S) Sociological self-report study on noise annoyance | About 20% of the representative sample was annoyed by noise; 90% of those were annoyed by road traffic noise | |
| Czech republic, 19 cities 1994-2006, since 2007 in 12 cities (with 2-3 year interval) Environmental Health Monitoring System in the Czech Republic, Summmary Reports 1998-2009, National Public Health Institute. (Kliment et al., 2000) | To assess environmental noise in selected towns of Czech Republic, to develop noise maps, to assess noise annoyance | Cross-sectional study | Sample of 4,987 questionnaires returned, 30-75 years | (O) Equivalent noise levels, maximal noise levels, L_{eq}=57 dB(AI) as limit value (S) Written and personal interview on noise annoyance | 1-quiet versus noisy area | (S) Self reported noise annoyance, sleep disturbance, health status | Noise associated annoyance was observed in 48% of respondents, but in the noisiest areas (L_{eq}>70 dB) 80% respondents reported annoyance. In quiet areas (L<55 dB) annoyance was reported by only 20% of respondents and the most frequent cause of annoyance was traffic noise | |

(Contd...)
Table 1: Contd...

| Location, country, town (reference) | Aim | Type of study | Sample | Exposure assessment | Covariates | Outcome | Findings |
|-----------------------------------|-----|---------------|--------|---------------------|------------|---------|----------|
| Czech Republic, 21 cities (Sisma, 2000)[29] | To find out what percentage of people who feel to be annoyed by noise, are ill civilization-determined diseases in relation to the noise level by which they are annoyed. To understand which illnesses are best characterized by the percentage of complaints | Cross-sectional study | Sample of 9,465 questionnaires (returned), 30-90 years Part of health-environmental monitoring | (O) $L_{A_{eq}}=48-75$ dB, $L_{A_{eq}}=37-69$ dB (S) Questionnaire, based on CINDL asking for selected health indicators (“civilization” diseases, neurotic syndromes etc.), demographic and sociologic data | 3=logistic regression analysis | (S) Self-reported health state | Statistically significant relationship between the increasing percentage of inhabitants feeling annoyed by noise and the occurrence of “civilization diseases”, mainly hypertension and frequent catarrhs of the upper respiratory tract |
| Student dormitory and residential areas, Bratislava, Slovakia (Sobotová et al., 2001)[30] (Radulov and Rolný, 1988; Aghová et al., 1990)[30] | To compare two noise annoyance surveys in ten-year interval (1989-1999) | Comparison of two cross-sectional studies | University students ($n_1=511$; $n_2=857$); exposed and control areas 40% males, 60% females, mean age 22.34+-1.32 years | (O) Mean 24 h equivalent noise levels (S) Noise annoyance questionnaire with 3 grade scale | 1=bivariate analysis, homogenous sample, stratification for gender, odds ratios | (S) Self-reported questionnaire survey | Increase of traffic noise load as well as subjective response to it during a 10-year interval (OR=2.56; 95% CI=1.93-3.42 vs OR=6.01; 95% CI=4.97-7.95) |
| Residential areas Warsaw, Poland (Koszarny, 2001)[37] | To estimate well-being and self-assessed health status in urban population | Cross-sectional study, sociological survey | 357 inhabitants living in noisy and moderate area | (O) Noisy area>70 dB(A), moderate<57 dB(A) (S) Questionnaire on annoyance, well-being and self-assessed health status | 1=group comparison, noisy versus moderate area | (S) Feeling of discomfort, irritation, nervousness, annoyance dominates in noisy area | Relative risk of unfavorably health symptoms in group of people from noisy areas was 1.5 times higher than in moderate areas, but morbidity rates were similar |
| General population, Slovakia (Dostál et al., 2002)[32] | To assess noise and annoyance in flats | Two cross-sectional studies | Sample of 578 respondents, 32.5 females, 56.2%, >18 years | (O) Maximal noise levels in flats (S) Annoyance, noise sensitivity | 0=no control | (S) Self-reported noise annoyance and sensitivity | Other important noise sources, e.g., footstep noise 36.5% annoyed |
| Ljubljana, Slovenia (Špes et al., 2002)[36] | Regionalization of Ljubljana based on noise pollution | Cross-sectional study | 1,252 adult citizens of Ljubljana | (O) 440 measurements at 112 locations in the city of Ljubljana (S) Noise disturbance questionnaire | 0=no control | (S) Subjective response of citizens in questionnaire | 36% of citizens--highly disturbed with noise, during the day 26.6%, during the night 23.3%, main source--traffic 64.1% |
| Cities Schwedt-Oder, former East Germany; Vilnius, Lithuania; Bratislava, Slovakia (Bonnefoy et al., 2003)[39] | To assess preliminary housing conditions in Eastern European countries and their potential health consequence (also regarding to noise exposure) | Field survey on panel block housing estates | Data collected from 259 dwellings, 601 adult residents, >16 years | (O) Visual inspection by surveyors, no physical measurements (S) Standardized housing questionnaire, self-administered health questionnaire, dwelling inspection sheet, noise annoyance on 5 grade scale | 1=group comparison (3 Eastern European cities) | 65% respondents in Vilnius, 40% in Bratislava, 36% in Schwedt-Oder claimed frequent noise disturbances, noise reported as priority problem in housing | Noise annoyance as one of the most important problems for residents’ health. Important sources--road traffic, neighbors, ventilation systems, lifts, industry, animals were identified |

(Contd...)
### Table 1: Contd...

| Location, country, town (reference) | Aim | Type of study | Sample | Exposure assessment | Covariates | Outcome | Findings |
|-------------------------------------|-----|---------------|--------|---------------------|------------|---------|----------|
| Respondents from towns Warsaw and Poznan, Poland (Preis et al., 2003)[30] | To develop a Polish version of noise annoyance scale | Empirical study | 30 adults respondents from Poznan and 30 – from Warsaw | (S) Noise annoyance questionnaire translated into Polish language | 1=group comparison | (S) The Polish words for scale were selected from the group of 21 potential adverbs | The most proper words for noise 5 point ICBEN verbal noise annoyance scale were developed (not at all, a little, rather, substantially, extremely) |
| Ljubljana, Slovenia (Toš, 2005)[31] | Public survey | Public survey | 1,000 citizens | (S) Noise annoyance questionnaire | 0=no control | (S) Social survey | The number of respondents disturbed by noise has increased from 19.6 to 33% in period 1973-2003 |
| Bratislava, Slovakia (Sobotová et al., 2006)[32] | To compare two noise annoyance surveys and two noise annoyance scales in the period of fifteen years, to calculate risks of community noise annoyance and disturbance | Comparison of two cross-sectional studies | Sample from 1989: 764 respondents, 36% males, 64% females, 71% aged 20-40 years, sample from 2004: 244 respondents, 36% males, 64% females, 80% aged 20-30 | (O) Mean 24 h equivalent noise levels (S) In 1989 - noise annoyance questionnaire with three grade scale, in 2004: Same questionnaire adjusted on five grade scale (according to Fields et al., 1997; 2001) | 1=bivariate and stratified analysis, odds ratios and Mantel-Haenszel weighted odds ratio | (S) Self reported questionnaire survey, percentage of highly annoyed subjects (% HA), rate of highly annoyed individuals | There was an increase of subjective community noise annoyance risks after 15 years: 22% vs 40% annoyed subjects by road traffic noise |
| Urban population, city centre of Belgrade, Serbia (Jakovljevic et al., 2008)[20] | To assess the effect of acoustical factors influencing noise annoyance of residents | Cross-sectional study | 1,836 adults: 776 men and 1060 women, Mean age 46+/−23 years | (O) Daytime, evening, night-time noise levels (L_n) in 70 streets, L_n, for day and night, number of vehicles (S) Self-reported numerical scale (range 0-10), high level noise annoyance – as score≥6 | 1=less annoyed versus highly annoyed 3=univariate logistic regression | (S) 36% highly annoyed in investigated area; main predictors of noise annoyance identified | Night-time noise level and number of heavy vehicles were the strongest predictors of high-level noise annoyance |
| Urban population, city center of Belgrade, Serbia (Paunovic et al., 2008)[21] | To assess the influence of personal and residential factors on noise annoyance of residents | Cross-sectional study | 2,155 middle aged residents: 1,003 men and 1,152 women, Mean age 42.4+/−16.8 years | (O) Daytime, evening, night-time noise levels (L_n) in 70 streets, L_n, for day and night, number of vehicles (S) Self-reported numerical scale (range 0-10), high level noise annoyance – as score≥6 | 1=low-level annoyance versus high-level annoyance 3=univariate and multivariate logistic regression | (S) 32.6% highly annoyed in investigated area | The strongest independent predictor for high level of noise annoyance was the orientation of bedroom toward street. Floor level was protective factor for high-level of noise annoyance |
| Poznan, Poland (Preis et al., 2005)[35] | To investigate if sound-source recognition influences annoyance | Two psychoacoustic experiments | 8 participants, paid; 9 participants, paid 19-22 years, normal hearing | (O) Six different reference stimuli, recordings of bus, tram, L eq, 70.5 dB(A), artificially modified original recordings (S) Judgment of annoyance on 11 point ICBEN scale | 1=original and modified noises | (S) Noise annoyance ratings of 6 different reference stimuli, original and modified noises | The annoyance judgments of two original signals in two experiments were not the same, the annoyance by hybrid-like noises was the same as the original recordings |
### Table 1: Contd...

| Location, country, town (reference) | Aim | Type of study | Sample | Exposure assessment | Covariates | Outcome | Findings |
|------------------------------------|-----|---------------|--------|---------------------|------------|---------|----------|
| Urban population, Belgrade, Serbia (Jakovljevic et al., 2009)²⁸ | To determine principal factors for noise annoyance in urban population and to assess their predictive value | Cross-sectional study | 3,097 adults: 1217 men and 1880 women 18–96 years | (O) Daytime, evening, night-time noise levels, $L_{den}$; number of vehicles (S) Questionnaire: Self-report five-graded scale | 3=correlation and multiple logistic regression | (S) 31% highly annoyed in investigated area; predictors of noise annoyance identified | Noise annoyance predictors: Night-time noise level, noise sensitivity, duration of stay at apartment, orientation of living room or bedroom |
| General population, Kaunas and Vilnius cities, Lithuania (Mačiūnas and Uscila, 2009)²⁹ | To evaluate annoyance and sleep disturbance caused by road traffic noise in Vilnius and Kaunas and their possible effect on public health | Exposure assessment of data, collected during the process of strategic noise mapping according to END | All residents of Vilnius and Kaunas cities | Noise level modeling, using GIS | Noise level modeling | The percentage of road traffic noise annoyed people in Kaunas is higher than in Vilnius: 4.87% vs. 3.97% highly annoyed; 12.04% vs. 9.75% moderately annoyed |
| Urban population, Belgrade, Serbia (Paunović et al., 2009)³⁰ | To assess the predictive value of various factors on noise annoyance in noisy and quiet urban streets | Cross-sectional study | 1,954 adults: 768 men and 1,186 women, 18–80 years | (O) 2 residential areas, quiet area $L_{den}<55$ dB(A), and noisy area $L_{den}>65$ dB(A) (S) Questionnaire: Self-report five-graded scale | 1=quiet versus noisy group 3=multivariate logistic regression | (S) 35.8% highly annoyed in noisy streets versus 23.7% highly annoyed in quiet streets; predictors of noise annoyance in quiet and urban streets identified | The relevant predictors of high annoyance in noisy streets were: The orientation of living room/bedroom toward the street, noise annoyance at workplace, and noise sensitivity. Significant acoustical factors for high noise annoyance: Night-time noise level, night-time heavy traffic or day–evening–night noise level ($L_{eq24h}$) |
| Skopje, Macedonia (Ristovska et al., 2009)³¹ | To identify noise exposure indicators during day and night and find out if there is an association between these indicators and annoyance | Cross-sectional study | 510 adults: 243 (47.65%) men and 267 (52.35%) women, 18–65 years | (O) Objective noise exposure assessment-noise measurements, $L_{day}$ ($L_{night}$ was 55 dB(A); $L_{day}$, (62±6.45) dB(A), $L_{night}$, (56±6.52) dB(A)). (S) Subjective annoyance evaluation, 5 point verbal scale and 11 point numerical scale | 1=Chi-square test 1= quiet versus noisy group 3= subjective annoyance ratings were obtained for different traffic scenarios and the most clustered distribution resulted in the lowest annoyance rating. These results correlated well with the averaged loudness, whereas the percentile loudness (N5) and level (L5) predict the opposite results |
| Poznan, Poland (Kaczmarek and Preis, 2010)³² | To investigate how the time structure of a road traffic affects the noise annoyance judgment | Psychoacoustic experiment | 19 participants: 19–24 years, normal hearing | (O) Four different noise scenarios as the stimuli, 110 dB(A). (S) Judgment of annoyance on 11-point ICBEN Scale | 1= different noise scenarios | (S) Noise annoyance ratings of 12 different noise scenarios (each of four types of scenarios was prepared in three independent realizations) | The highest annoyance ratings were obtained for even traffic distribution and the most clustered distribution resulted in the lowest annoyance rating. These results correlated well with the averaged loudness, whereas the percentile loudness (N5) and level (L5) predict the opposite results |
Aim
To estimate specific local patterns of reaction and response to urban noise as a consequence of strategic noise mapping

Type of study
Sociological survey

Sample
348 respondents, 51.4% females; 63.1% university graduates; 55.1% between 31–60 years

Exposure assessment
(L) Aeq in streets often >64 dB(A) (S) Noise annoyance questionnaire, 24 questions

Outcome
O = objective (measurement or clinical examination), S = subjective (self-reported questionnaire survey)

Findings
37% of respondents annoyed by noise; 75% of respondents annoyed in 75% respondents

Table 1: Contd...
road traffic noise annoyance in Eastern Germany conducted during 1988-1994 by Schulze and Wölke in the city of Erfurt. Around 20% of the respondents (1000 adult citizens of the city Erfurt) was annoyed by noise, and 90% of these were annoyed particularly by road traffic noise.

In the Czech Republic, environmental noise and its effects on health are observed since 1994 through the environmental health-monitoring system. According to the results published by Sisma in 2000, 64% of the population annoyed by noise suffered from one or more “civilization-related” diseases (such like hypertension, myocardial infarction, gastric and duodenal ulcers, cholelithiasis and urolithiasis, diabetes mellitus, tumors, and frequent catarrhs of the upper respiratory tract). This phenomenon was statistically significant in populations affected by noise levels higher that 55 dB at night. As a result of “Health and Noise” questionnaire survey in 2007 (also part of Czech environmental health monitoring), 4987 responses were collected. The participants expressed the degree of annoyance on a six-point scale ranging from ‘not at all’ to ‘very high’. Noise annoyance was registered at the upper end of this scale (the three higher points). In the whole sample, 48% of respondents were affected by noise, but in the noisiest localities, this number increased to 80%. The most frequent cause of disturbance was automobile traffic which disturbed 59% of all the respondents on a daily basis.

Belojević et al., in 1992 explored the importance of subjective noise sensitivity in mediating the effects of noise on mental performance. The results showed that annoyance while performing tasks under noisy conditions was higher among subjects judged to be noise-sensitive on Weinstein’s scale, compared to those who were judged to have low or moderate subjective noise sensitivity. In later studies, the Belgrade team for biological effects of noise (BETBEN) has studied the principal factors for noise annoyance in the urban Belgrade population. In the most recent population studies, this research team found that the strongest predictors of high noise annoyance were: Subjective noise sensitivity, orientation of windows toward the street in bedrooms or/and living rooms, duration of stay in the apartment, number of heavy vehicles, night-time noise levels, and noise annoyance at the workplace. In the study by Jakovljevic et al., (2009), the residents considered traffic noise much more disturbing/annoying than the neighborhood noise, although noise itself was not regarded the most important environmental hazard in the investigated municipality of Belgrade. Cultural differences may explain the observed inconsistencies. It might be also a reason why many field studies find that noise levels could only partially explain the extent of annoyance in the exposed populations. Paunović et al., (2009) showed that noise-related characteristics were less significant predictors of noise annoyance than personal, social, and housing characteristics. The authors stated that noise levels were important indicators of annoyance only in
noisy streets and that night-time noise levels and composite day-evening-night noise levels ($L_{den}$) shared similar predictive values. Therefore, they suggested that night-time $L_{eq}$ might be as good as $L_{den}$ in predicting noise annoyance in noisy urban areas.\textsuperscript{[9]} BETBEN team proposed a four-step pyramidal model for the explanation of noise annoyance. In the base of the model, they placed subjective noise sensitivity, which was independent from noise exposure. The second step included personal perception, expectations, and attitudes toward noise, influenced by personality traits, social status, housing, and working conditions. The third step was formed from some characteristics of noise exposure (sources of noise, type of traffic, number of events, frequency, and time of exposure). Finally, noise exposure level was placed on the top of the pyramid as annoyance indicator in noisy urban areas.\textsuperscript{[9]}

In the Former Yugoslav Republic of Macedonia, the cross-sectional study was performed to identify annoyance level in relation to noise exposure in Skopje.\textsuperscript{[27]} This cross-sectional study was the first national study assessing noise-induced annoyance in adult population. It was designed as the questionnaire-based survey on noise annoyance and health status. Noise exposure indicators-day equivalent sound level ($L_{den}$), night equivalent sound level ($L_{night}$), and $L_{eq}$ were determined and subjective noise annoyance was evaluated on a 5-point verbal scale and an 11-point numerical scale. Results showed that 13% of the subjects were highly annoyed by noise, 33.5% were moderately annoyed, and 53% were not annoyed at all. According to noise sources and the five-item verbal scale, the most annoying noise came from construction activities, followed by road traffic noise and leisure activities, such as entertainment activities in public places and noise from restaurants and cafeterias.\textsuperscript{[27]}

In Bratislava, Slovak Republic, two noise annoyance surveys were performed in a 10-year interval (1989-1999). This was a period of political and socioeconomic transformations as well as changes in traffic management. Comparing recent and former risks of different noise exposures, the study has found that the load of community noise, especially road traffic noise, as well as the subjective response to noise had increased in Bratislava. The strength of this study was the comparison in a 10-year interval.\textsuperscript{[28-30]} Later, the same group of scientists performed another noise annoyance survey and compared its results with the results from earlier studies.\textsuperscript{[10]} Therefore, they compared two noise annoyance surveys (from 1989 to 2004) and two noise annoyance scales (the new and previously suggested five-grade scale and three-grade scale as standard approach) in the period of 15 years in Bratislava. The authors concluded that the use of five-grade noise annoyance questionnaire provides better possibilities for the assessment of environmental noise annoyance in selected population. The authors of the last Bratislava study used a new indicator—percentage of highly annoyed (% HA) persons. This indicator enables the comparison of results from other European and world studies.\textsuperscript{[10]} In other cross-sectional study from Bratislava, Slovakia, (1992) noise annoyance assessment revealed that almost half (49.6%) of the studied adult inhabitants, exposed to noise levels higher than 50 dB (A), were annoyed by noise.\textsuperscript{[31]} One more Slovak study focused on evaluation of the acoustic comfort in a dwelling area with apartment houses built in Slovakia by the prefabrication technology, and investigation of the possible negative impact of non-specific effects on the health of the population was identified. The noise annoyance was assessed in the flats and the use of sleeping pills was discussed. In this study, 36.5% out of 578 respondents found the foot-step noise to be annoying in the panel houses and 59 respondents out of 450 stated using of sedatives and hypnotics in relation to annoying environmental noise in the surroundings.\textsuperscript{[32]}

A search performed through different information sources has shown that in Slovenia, there are no epidemiological studies on environmental noise and related health effects. We were able to identify a general public opinion survey,\textsuperscript{[33]} which showed that the proportion of residents disturbed by noise has increased from 19.6% to 33% and the proportion of those more disturbed has increased from 16.5% to 19.3% in the period of thirty years (1973-2003). Correspondingly, the proportion of residents thinking that noise is not a problem in their environment has dropped from 36.5% to 21.4% in the same period.\textsuperscript{[33]} The results of other survey by Špes et al., (2002) indicated that 36% of participants were over-burdened by noise in the city and that 64.1% of all participants indicated that road traffic noise was the most disturbing source of noise in Ljubljana.\textsuperscript{[34]}

In the recent psychoacoustic experiments in Poland, Kaczmarek and Preis (2010) found that the structure of traffic flow (and the resulting shape of a time pattern) can influence annoyance judgments of traffic noise inside the building.\textsuperscript{[35]} The same group of researchers in two other psychoacoustic experiments tested a hypothesis stating that if annoyance is influenced by sound-source recognition, differences between annoyance ratings of the original and modified noises could be expected; and in contrary, if there are no differences in annoyance ratings of both sounds, the sound-source recognition influences annoyance perception insignificantly. The results showed that the annoyance judgments of two original signals in two experiments were not identical; the annoyance by hybrid-like noises was the same as the original recordings.\textsuperscript{[36]} In the other Polish study, Koszarny (2001) found that the relative risk of appearance of unfavorable health symptoms (e.g., feeling of discomfort, annoyance, mental pressure caused by noise etc.) was 1.5 times higher among people from noisy areas (noise levels above 70 dB[A]) compared to persons from moderately noisy areas (noise levels below 57 dB[A]).\textsuperscript{[37]} An internationally comparable noise reaction measure for social surveys was published by Fields et al., as a result of work performed by the Community Response to Noise Team of the ICBEN.\textsuperscript{[4]} Preis et al., 2003 developed a Polish version of a noise annoyance scale with
the most proper words of the 5-point ICBEN verbal noise scale. This adaptation was a result of the participation of Poland in the world network of countries, using the same method for the estimation of noise annoyance. Usage of such a scale permits Polish data to expand the world database on human reactions to noise and become more comparable with the data from other countries.

In the Pan-European study done in several Eastern European cities (former Eastern Germany, Lithuania and Slovakia), noise annoyance was recognized as one of the most prevalent problems affecting residential health and well-being. This field study was performed by the WHO and aimed to highlight housing and health problems of Eastern European countries in transition that could be related to living conditions in panel block buildings. Due to their building style, several housing-related health threats are typical for these types of buildings, with the neighborhood noise being one of the most frequent problems. Study results showed that in all three analyzed countries, noise exposure was between the most stable factors affecting the perception of health. It was found that the insulation measures and renovation only partially diminished the noise exposure and there were no great differences found between building types. Noise, therefore, emerged as the most pervasive factor influencing health and residential quality in this study, although it cannot be described as the most serious threat to health and well-being. The sample size was small, but a more powerful sample might give a clearer and more conclusive answer to this crucial question in the future studies.

The selected studies on environmental noise and road traffic noise annoyance were mostly cross-sectional studies; some were experimental or social surveys. In the cross-sectional studies, noise annoyance was measured mainly using self-reported questionnaires. Very often, group comparison was used to evaluate the difference between noise-exposed and unexposed urban residents. For the countries where several studies were identified, it was generally the same team of scientists working on a specific subject related to noise annoyance. For example, in Belgrade in Serbia, the same group of researchers was working on the principal factors for noise annoyance, whereas in Slovakia a group of scientists concentrated their work on the comparison of noise annoyance surveys for urban residents from Bratislava in ten-year periods. In Poland, scientists mostly performed psychoacoustic experiments in laboratory conditions on factors influencing noise annoyance judgments. Therefore, studies design and methodologies are often similar inside each country, but are different between the countries.

**Noise annoyance from other noise sources**

The earliest studies identified in our review were from the former USSR and different noise sources were studied for assessing environmental noise annoyance [Table 2]. Karagodina et al., (1969) investigated aircraft noise and its effects on population residing within a radius of 40 km from airports, whereas Volkov et al., (1972) evaluated the response of public on railway transport noise. Polish scientists published several studies investigating effects of low-frequency noise (LFN) on human health. For example, Mirowska and Mroz evaluated a long-lasting effect of LFN on health of dwellers in the residential buildings. The tests referred to adults living in dwellings where LFN occurred from appliances installed in the building and where at least one person from that flat complained about noise nuisance. The results showed that people considered LFN as annoying or very annoying even at very low levels, not exceeding the acceptable values of A-weighted sound levels. The exposure to such LFN may create depression states or even intensify a degree of pre-existing depression, of which the person is unaware. Other two identified Polish studies related to LFN were performed under laboratory conditions. The results of Pawłaczyk-Luszczynska et al., (2005) showed that highly sensitive subjects reported being highly annoyed by noise. The findings also suggested that LFN at moderate levels might adversely affect visual functions, concentration, continuous and selective attention, especially in subjects highly sensitive to LFN. In a later study, the same group of authors investigated the annoyance by LFN at levels normally prevailing at workplaces, such as control rooms and office-like areas. The results of two experiments showed a significant influence of individual sensitivity to noise on annoyance rating for some LFNs. The authors of the study also predicted that more than half of the subjects were highly annoyed by LFN at the low frequency A-weighted sound pressure level (SPL) or C-weighted SPL above 62 and 83 dB respectively.

Very few studies on environmental noise and noise annoyance from other noise sources were identified. In the recent studies, Polish researchers were investigating the annoyance of LFN under laboratory conditions or in residential buildings, whereas only two previous studies were identified on aircraft noise and railroad noise. Comparing with the research performed in Western Europe, there is a big gap and lack of well-designed studies on environmental noise annoyance from aircraft noise, and particularly, from railway noise.

**European Union policy implications related to annoyance in Central and Eastern Europe, South-East Europe and Newly Independent States**

European Environmental Agency (EEA) and EU Member States are currently assessing noise data collected in the context of the EU END first round of noise mapping in Europe including major agglomerations and major roads, and will repeat the exercise in the following round for smaller agglomerations and roads. These data seem attractive for researchers working on noise and health issues, but the data must be analyzed and critically reviewed case by case. Therefore, in this review, we also looked for the studies performed in CEE, SEE, and NIS countries, which already
Table 2: Studies on other noise sources (aircraft, railway and low frequency noise) and health in adults in Central and Eastern Europe, South-East Europe and newly Independent States

| Location, country, town (reference) | Aim | Type of study | Sample | Exposure assessment | Covariates | Outcome | Findings |
|-------------------------------------|-----|---------------|--------|---------------------|------------|---------|----------|
| Nine airports, 22 settlements in the former USSR (Karagodina IL et al., 1969) | To investigate parameters of aircraft noise and effects on population 40 km from the airports | Cross-sectional study | 2000 residents, in 22 settlements, adults | (O) Noise data not analyzed with responses (S) Subjective evaluation-questionnaire on noise complaints | l=close to versus far from airport | (S) 60-94% complaints from people living 5-10 km from the airport, mostly over 41 years old, living in the area>5 years | Disturbance with aircraft noise was related to distance from airports |
| Residential areas 40-300 m from railways, Moscow, former USSR (Volkov AM et al., 1972) | To evaluate the response of public on railroad transport noise based on data from a questionnaire and word association tests | Social survey | 227 respondents, 2/3 women, 20 years (13), 21-40 years, (101)-41 years (113), living 3-6 months in the area, 15 students not exposed to transport noise | (O) Noise levels up to 91-93 dB(A), 95-99 dB(A) acoustic signals (S) Noise complaints from people living 40-100 m from the railway, 87% complained on anxiety and irritation | l=15 students not exposed to transport noise - control group | (O) Word association test performed to assess noxious effect on CNS | Noise caused inconvenience to the population; prolongation of the latent period in the reply reaction at the time of carrying out the verbal-association experiment |
| Residential areas, Warsaw, Poland (Mirowska M and Mroz E. 2000; Mirowska M, 2002) | To determine LFN annoyance in the exposed and control group of citizens | Epidemiological study, Cross-sectional study | 49 residents, > 18 years, 27 – exposed group, who complained about LFN, 22 – control group | (O) LFN from appliances (L,F) installed inside or outside the buildings, permissible sound values not exceeded, low frequency noise present at group T (S) Questionnaire about the effects of low frequency noise (LFN), Questionnaire for assessment Behavior Models, The Beck`s depression test; Wrzesniewski`s test for Investigating Behavior Models | l=group comparison, group T–exposed to LFN, group C–control | (S) Personal interview, higher frequency of reported chronic fatigue, heart ailments, chronic insomnia and other health problems in test group | LFN that is near the hearing threshold can be annoying and creating a potential health hazard for the dwellers |
| Laboratory setting, Lodz, Poland (Pawłaczyk-Łuszczyńska et al., 2005) | To assess the influence of low frequency noise on human mental performance and subjective well-being | Experimental study | 191 male volunteers | (O) Laboratory noise -30 dB(A), LFN, broadband noise 50 dB(A) (S) Standardized tests | l=group comparison, exposed and not exposed to LFN | (S) Signal Detection, Stroop, General Aptitude Test, Reasoning, Comparing of Names Test | No effects found due to LFN on mental performance compared to background and reference noises; higher annoyance in highly sensitive subjects |
| Laboratory setting, Lodz, Poland (Pawłaczyk-Łuszczyńska M et al. 2003; Pawlaczcyk-Luczynska et al., 2010) | To investigate the annoyance of low frequency noise | Experimental study | 1st experiment - 55 volunteers, 27 females and 28 males, 18-28 years. 2nd experiment-70 volunteers, 48 females and 22 males, 36-60 years | (O) Noise samples of different spectra, LFN at sound pressure 45-67 dB(A) (S) Annoyance questionnaire 100-score graphical rating scale | l=group comparison, between two experiments | (S) Personal interview, Weinstein noise sensitivity questionnaire, LFN questionnaire | Over half of the subjects were highly annoyed by LFN at SPL above 62 and 83 dB(A), no difference between females and males |

CNS = Central nervous system, LFN = Low frequency noise, dB = decibel, SPL = Sound pressure level, Exposure assessment - O=objective (noise level outdoors), S = subjective (annoyance), Covariates - 0 = no control, 1 = group comparison, 2 = stratification or standardization, 3 = model adjusted (regression), 4 = matching, Outcome - O = objective (measurement or clinical examination), S = subjective (self-reported questionnaire survey)
The multi-country study described in the introduction aimed to evaluate the noise exposure and annoyance levels in different European countries. It was conducted in CEE, SEE, and NIS countries, which are not fully familiar with the concept of noise exposure and its impact on health. The study was designed to fill the gap in knowledge about the effects of environmental noise in these regions.

The results of our review show that research work on environmental noise and annoyance was conducted in CEE, SEE, and NIS countries from 1969 to 2010 mostly using cross-sectional studies, less often – experimental studies. In the cross-sectional studies, noise annoyance was measured using self-reported questionnaires. Very often, group comparison was used to evaluate the difference between noise-exposed and unexposed urban residents. For the countries for which we identified three or more published studies, we also found out that it was mostly one team of scientists working on specific subject related to noise annoyance. The studies included to this review present very interesting findings related to noise and annoyance assessment, which, in spite of differences and some inconsistencies in methodology, help to fill in the gap in the knowledge in CEE, SEE, and NIS countries. However, there is a lack of recent studies on railway and aircraft traffic and annoyance, as a dominant noise source in the identified papers was road traffic noise. There is an increasing interest between researchers in EU Member States to use noise exposure data, collected as required by END. Some of SEE and NIS countries, not being EU Member States, also show a considerable interest to adopt the forthcoming harmonized methods (CNOSSOS-EU) and to develop a common methodology for assessment of burden of diseases from environmental noise in European countries. Therefore, capacity building in CEE, SEE, and NIS countries is necessary for “know-how”, to implement, and use the different scenarios for evaluating population annoyance by environmental noise, depending on the availability and suitability of noise exposure data.

Conclusions

The research leading to these results has received funding from the European Union’s Seventh Framework Programme (FP7/2007-2013) under grant agreement No 226442.

Acknowledgement

The Lithuanian study aimed at evaluating annoyance and sleep disturbance caused by road traffic noise in Vilnius and Kaunas and their possible effect on public health. According to the results of the strategic noise mapping, 7.1% of Vilnius population and 6.68% of Kaunas population were exposed to road traffic noise exceeding noise limits of $L_{den}$. The adverse effects on public health caused by road traffic noise were evaluated using the dose-effect relationships between annoyance and $L_{den}$ for road traffic noise. Therefore, the strategic noise mapping results showed that the percentage of total urban population of the city annoyed by road traffic noise at day, evening, and night in Kaunas was higher than that in Vilnius. 3.97% of Vilnius population was highly annoyed, 9.75% was moderately annoyed, and 18.48% was lightly annoyed. In Kaunas: 4.87% of population was highly annoyed, 12.04% was moderately annoyed, and 22.93% was lightly annoyed. The results of the second round of strategic noise mapping in the five biggest Lithuanian cities will enable to create more comprehensive knowledge about noise exposure and its effect on the population.

In Cluj-Napoca city, Romanian researchers conducted a social survey, which helped to evaluate the population response to urban noise and to provide information for developing action plans and better solutions for urban planning. The need of such a survey appeared in the context of strategic noise mapping. The results of the Romanian study suggest that as the reported equivalent sound pressure level ($L_{Aeq}$) values frequently exceeded 64 dB (A), it can be considered that the respondents were habituated to the noise in their residential area. Most respondents (46%) reported to be slightly annoyed, 37% annoyed, and 6% not at all annoyed by the environmental noise. Road traffic noise was reported as being one of the most frequent and annoying noise sources near home (75% of all responses), whereas 51% of respondents were most affected and disturbed by noise during the afternoon and evening (15:00-22:00). This study also concluded that the inhabitants were interested in reducing the annoying noise and improving acoustical environment, but they did not receive sufficient information on this topic.

Our results show that the use of END noise exposure data for annoyance evaluation in population is only at the starting point, concerning CEE, SEE, and NIS countries. Some of these countries are not members of the EU and they are not obliged to adopt the END Directive, but they show a considerable interest to adopt the harmonized methods for noise exposure assessment (CNOSSOS-EU) and use the data from a strategic noise mapping for health studies. A lot of harmonization work still has to be done, but the European Commission Directorate General Environment, Directorate General Joint Research Centre, WHO, and EEA already established some collaboration for joining efforts to protect the public health from environmental noise. As proposed by experts on noise and health during the meeting at WHO, continuous efforts from the leading institutions are needed for the development of a common method for assessing the burden of disease from environmental noise in European countries. Different methods have to be proposed to the countries that have already produced strategic noise maps, and alternative method for other countries planning to prepare strategic maps.

Acknowledgement

The research leading to these results has received funding from the European Union’s Seventh Framework Programme (FP7/2007-2013) under grant agreement No 226442.

Address for correspondence:
Dr. Jurgita Lekaviciute,
European Commission - Joint Research Centre,
Institute for Health and Consumer Protection, Chemical Assessment and Testing Unit, TP 281, Via E. Fermi, 2749, I-21027 Ispra (VA), Italy.
E-mail: jlekaviciute@gmail.com
References

1. Hänninen O, Knol A. European perspectives on environmental burden of disease. Estimates for nine stressors in six European countries. Report 1/2011. Helsinki: National Institute for Health and Welfare (THL); 2011. p. 86. Available from: http://www.thl.fi/thl-client/pdfs/b75f6999-e7c4-4550-a939-3bcb19e4c11. [Last accessed on 2012 Nov 27].

2. Kluebo R. Noise and health: Annoyance and interference. In: Niriag JO, editor. Encyclopedia of Environmental Health. Burlington: Elsevier; 2011. p. 152-63.

3. Fields JM, De Jong RG, Brown AL, Flindell I, Gjestland T, Job R, et al. Guidelines for reporting core information from community noise reaction surveys (The International Commission on the Biological Effects of Noise). J Sound Vib 1997;206:685-95.

4. Fields JM, De Jong RG, Gjestland T, Flindell IH, Job RF, Kurra S, et al. Standardized general-purpose noise reaction questions for community noise surveys: Research and a recommendation. J Sound Vib 2001;242:641-79.

5. Öhrström E, Skånberg A, Svensson H, Gidlöf-Gunnarsson A. Effects of road traffic noise and the benefit of access to quietness. J Sound Vib 2006;295:40-59.

6. Öhrström E. Longitudinal surveys on effects of changes in road traffic noise-annoyance, activity disturbances, and psycho-social well-being. J Acoust Soc Am 2004;115:719-29.

7. International Organization for Standardization, ISO 1996-1 Acoustics – Description, measurement and assessment of environmental noise – Part 1: Basic quantities and assessment procedures. Geneva: International Organization for Standardization; 2003.

8. Ouis D. Annoyance from road traffic noise: A review. J Environ Psychol 1992;1:101-20.

9. Paunovíc K, Jakovljević B, Belojević G. Predictors of noise annoyance in noisy and quiet urban streets. Sci Total Environ 2009;407:3707-11.

10. Sobotová L, Jurkovičová J, Voleková J, Aghová L. Community noise and annoyance assessment in an urban agglomeration. Bratisl Lek Listy 2006;107:214‑6.

11. Directive 2002/49/EC.Directive of the European Parliament and of the Council of 25 June 2002 relating to the assessment and management of environmental noise. Official J Eur Communities 2002;L180:23-25.

12. European Commission. Report from the Commission to the European Parliament and the Council on the implementation of the Environmental Noise Directive in accordance with Article 11 of Directive 2002/49/EC. Brussels; 2011. Available from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0321:FIN:EN:PDF. [Last accessed on 2012 Nov 27].

13. Argalasova-Sobotova L, Paunovic K, Belojevic G, Jeram S, Ristovska G, Lekaviciute J, et al. Highlights on environmental noise and health research in Central and Eastern Europe, South-East Europe and Newly Independent States. In: Imaizumi H, editor. Proceedings of INTER-NOISE 2011. The 40th International Congress and Exposition on Noise Control Engineering, "Sound Environment as a Global Issue". Tokyo: The Institute of Noise Control Engineering of Japan and the Acoustical Society of Japan, 2011. p. 1-15.

14. Suvorov GA, Briqueur K, Miueller V, Shkarinov LN, Denisov EI. Effect on human physiologic functions of variable noise with different time structures (Vliyanie na nekotorye fiziologicheskie funktsii organizma cheloveka nepostoyannykh shumov razlichnykh vremennykh struktur). Gig Tr Prof Zabol 1986;4:17-20.

15. Schulze B, Wölke G, Mörstedt R, Ullmann R, Grossmann G. Street traffic noise and stress experience. Z Gesamte Hyg 1990;36:201-3.

16. Wölke G, Mahr B, Kahl G, Mörstedt R, Schulze B. Traffic noise and cardiovascular risk (Verkehrslärm und kardiovaskuläres Risiko). Forum Stüde-Hygiene 1990;41:306-8.

17. Schulze B, Grossman G. Traffic noise and cardiovascular risk (Verkehrsgepin und kardiovaskuläres Risiko). Bundesgesundbl 1092; 1992.

18. Schulze B. Dependence of noise-induced individual and group reactions on stimulus variables and moderators in the reference laboratory for community noise production of former East Germany. Gesundheitswesen (Bundesverband der Ärzte des Öffentlichen Gesundheitsdienstes (Germany)) 1994;56:152-4.

19. Kliment V, Kubinová R, Kazmarová H, Kratzer K, Sisma P, Ruprich J, et al. Five years of the system of monitoring the environmental impact on population health of the Czech Republic. Cent Eur J Public Health 2000;8:198-205.

20. Sisma P. Health significance of data on annoyance by ambient noise. In: Inter-noise 2000. Nice, France; 2000.

21. Dobšík O, Vandasová Z. Noise annoyance and health effects. In: Puklová V, editor. Environmental Health Monitoring System in the Czech Republic. Summary Report – 2007. Prague: National Institute of Public Health; 2008. p. 37-40. Available from: http://www.szu.cz/uploads/documents/chzp/souhrna_zprava/Summary_report_07.pdf. [Last accessed on 2012 Nov 27].

22. Belojević G, Ohrström E, Rylander R. Effects of noise on mental performance with regard to subjective noise sensitivity. Int Arch Occup Environ Health 1992;64:293-301.

23. Jakovljević B, Paunovic K, Belojević G. Road traffic noise and factors influencing noise annoyance in an urban population. Environ Int 2009;35:552-6.

24. Jakovljević B, Belojević G, Paunovic K. Acoustical factors influencing noise annoyance of urban population. In: Griefahn B, editor. 9th International Congress on Noise as a Public Health Problem (ICBEN). Mashantucket, Connecticut, USA. July 21-25, 2008. p. 639-43.

25. Paunovic K, Jakovljevic B, Belojevic G. The importance of non-acoustical factors on noise annoyance of urban residents. In: Griefahn B, editor. 9th International Congress on Noise as a Public Health Problem (ICBEN). Mashantucket, Connecticut, USA. July 21-25, 2008. p. 684-7.

26. Guski R. Personal and social variables as co-determinants of noise annoyance. Noise Health 1999;1:45-56.

27. Ristovska G, Gjorgiev D, Polozhani A, Kocubovski M, Kendrovski V. Environmental noise and annoyance in adult population of Skopje: A cross-sectional study. Arh Hig Rada Toksikol 2009;60:349-55.

28. Sobotová L, Jurkovičová J, Voleková J, Aghová L. Community noise annoyance risk in two surveys. Int J Occup Med Environ Health 2001;14:197-200.

29. Radulov S, Rolny D. Noise in the environment of some Slovak towns and community noise annoyance. Acta Hyg Epidemiol Microbiol 1988;9:120-7.

30. Ćirgojevic N, Jeram S, Bajo J, Djurovic A, Crnokrunac D. Use of sedatives and hypnotics-the problem of not coping with neurotizing noise (Uživanje sedativ a hypnotík‑riešenie problému nezvládania neurotizujúceho hluku). Hygiéna 2002;47:197-201.

31. Toš N. Values in transition I–IV. Slovenian Public Opinion (1968-2009) (Vrednote v prehodu I.‑IV. Slovensko javno mnenje (1968-2009)). Centre for research of public opinion and mass communication, Institute of Social Sciences, Faculty of Social Sciences, University of Ljubljana. 2005.

32. Dostál A, Janušová T, Szárazová M, Brodniansky B. Use of sedatives and hypnotics-the problem of not coping with neurotizing noise (Uživanje sedativ a hypnotík‑riešenie problému nezvládania neurotizujúceho hluku). Hygiéna 2002;47:197-201.

33. Preis A, Háfek H, Kaczmarek T. Influence of sound source recognition on annoyance judgment. Noise Control Eng J 2008;56:288-99.

34. Koszarny Z. The estimate of well‑being and self‑assessed health status. Inštitut za geografijo, Ljubljana; 2002. p. 82.

35. Kaczmarek T, Preis A. Annoyance of time‑varying road traffic noise. Arch Acoust 2010;35:552‑6.

36. Preis A, Hafke H, Kaczmarek T. Influence of sound source recognition on annoyance judgment. Noise Control Eng J 2008;56:288-99.

37. Lekaviciute and Argalasova-Sobotova: Environmental noise and annoyance in adults
version of standardized noise reaction questions for community noise surveys. Int J Occup Med Environ Health 2003;16:155-9.
39. Bonnefoy X, Braubach M, Krapavickaite D, Ormandy D, Zurlyte I. Housing conditions and self-reported health status: A study in panel block buildings in three cities of Eastern Europe. J Housing Built Environment 2003;18:329-52.
40. Karagodina IL, Soldatkina SA, Vinokur IL, Klimukhin AA. The effect of aircraft noise on the population living in the vicinity of airports. Gig Sanit 1969;34:25-30.
41. Volkov AM, Karagodina IL, Tsitsar’ AI, Soldatkina SA, Shishkina VV. Public evaluation of railroad transport noise (based on data from a questionnaire and word association tests). Gig Sanit 1972;37:29-32.
42. Mirowska M, Mroz E. Effect of low-frequency noise at low levels on human health in light of questionnaire investigation. In: Proceedings of Inter-noise 2000. The 29th International Congress and Exhibition on Noise Control Engineering, Nice, France. 2000;5:2809-12.
43. Mirowska M. An investigation and assessment of annoyance of low frequency noise in dwellings. Noise Notes 2002;1:30-4.
44. Pawlaczyk-Luszczynska M, Dudarewicz A, Waszkowska M, Szymczak W, Sliwinska-Kowalska M. The impact of low-frequency noise on human mental performance. Int J Occup Med Environ Health 2005;18:185-98.
45. Pawlaczyk-Luszczynska M, Dudarewicz A, Waszkowska M, Sliwinska-Kowalska M. Assessment of annoyance from low frequency and broadband noises. Int J Occup Med Environ Health 2003;16:337-43.
46. Pawlaczyk-Luszczynska M, Dudarewicz A, Szymczak W, Sliwinska-Kowalska M. Evaluation of annoyance from low frequency noise under laboratory conditions. Noise Health 2010;12:166-81.
47. Lekaviciute J, Kephalopoulos S. Usefulness of strategic noise maps as exposure data for estimating the environmental burden of disease from environmental noise. In: Hellmuth T, Classen T, Kim R, Kephalopoulos S, editors. Methodological guidance for estimating the burden of disease from environmental noise. World Health Organization Regional Office for Europe -Joint Research Centre. Copenhagen; 2012. Available from: http://www.euro.who.int/__data/assets/pdf_file/0008/179117/Methodological-guidance-for-estimating-the-burden-of-disease-from-environmental-noise-ver-2.pdf [Last accessed on 2013 Jan 10].
48. Mačiūnas E, Uscila V. Evaluation of annoyance and sleep disturbance caused by road traffic noise in Vilnius and Kaunas (Kelių transporto triukšmo sukeliamos žmonių dirginimo ir miego trikdymo vertinimas Vilniuje ir Kaune). Health Sciences 2009;3:2383-7.
49. Popescu DI, Moholea IF. Monitoring the reaction and response of people to urban noise. Arch Acoust 2010;35:237-44.
50. World Health Organization. Burden of disease from environmental noise: Practical guidance. Report on a Working Group Meeting, Bonn, Germany, 14-15 October 2010. Copenhagen; 2011.Available from: http://www.euro.who.int/__data/assets/pdf_file/0004/131809/e94731.pdf. [Last accessed on 2012 Nov 28].

How to cite this article: Lekaviciute J, Argalasova-Sobotova L. Environmental noise and annoyance in adults: Research in central, eastern and south-eastern Europe and newly independent states. Noise Health 2013;15:42-54.

Source of Support: European Union’s Seventh Framework Programme (FP7/2007-2013) under grant agreement No 226442., Conflict of Interest: None declared.
