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ENVIRONMENTAL NOISE IN NOVI SAD 1985 − 2016

BUKA U ŽIVOTNOJ SREDINI U NOVOM SADU 1985–2016

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Summary

Introduction. Noise is recognized as a physical hazard in the environment, and if it causes adverse effects to human health, it is recognized as a risk. Also, it is a harmful outdoor sound created by human activity. The aim of this paper was to present the history of environmental noise measurements in Novi Sad, as well as the indicators, methods, standards and results during three decades. **Material and Methods.** From 1985 to 2011, the Institute of Public Health of Vojvodina conducted noise measurements presented as the equivalent continuous sound pressure levels, which were, at the same time, the rating equivalent continuous levels, due to the representativity of the measurement conditions and measurement sites selection. Since 2011, the measurements have included the basic noise indicators - daily, evening, night and total noise, while the measurement sites were ranked in accordance to the European Environmental Noise Directive. **Results.** There is a lot of available data about environmental noise in Novi Sad from 1985 − 2016, but only the data from five representative measurement sites are presented in the paper. The linear trends of daily and night noise from all the measurement sites show a fall, but it does not mean that the environmental noise is reduced. All the data show that the minimum and maximum values are getting close to each other, which indicates that environmental noise is evenly distributed and is present everywhere. **Conclusion.** Based on the 30-year results, always using modern methodology and equipment, as well as expert knowledge, it may be concluded that the environmental noise in Novi Sad presents a long-lasting physical hazard.

Key words: Cities; Noise; Environment; Risk Factors; Public Health; Equipment and Supplies; History of Medicine

Sažetak

Uvod. Buka je prepoznata kao fizička opasnost koja se, ukoliko ugrožava zdravlje i dovodi do obolevanja stanovništva, prepoznaje kao rizik iz životne sredine, odnosno buka u životnoj sredini je neželjeni/štetni zvuk stvoren ljudskom aktivnošću. Cilj rada je da se prikažu: istorijat merenja buke u životnoj sredini u Novom Sadu, korišćeni pokazatelji, metode, normativi i rezultati merenja za prethodne tri decenije. **Materijali i metode.** Od 1985. do 2011. godine, rezultati merenja koja je sprovodio Institut za javno zdravlje Vojvodine prikazivani su kao vrednosti ekvivalentnog nivoa buke, koji je bio istovremeno i merodavni nivo buke usled reprezentativnosti uslova merenja i izbora mernih mesta. Od 2011. godine određuju se vrednosti osnovnih indikatora buke − indikatora dnevne, večernje, noćne i ukupne buke, a merna mesta se rangiraju u skladu sa evropskom direktivom. **Rezultati.** Od izobilja raspoloživih podataka o merenju buke u Novom Sadu u periodu 1985−2016. godine, u radu su prikazani samo podaci sa pet reprezentativnih mernih mesta. Linerarni trendovi dnevne i noćne buke na svim mernim mestima pokazuju pad, ali to ne znači da se buka u životnoj sredini smanjuje. Istorijski podaci pokazuju da se minimalne i maksimalne vrednosti približavaju jedne drugima, što ukazuje na to da se buka u gradu „ravnomerno raspoređuje" i da je svuda prisutna. **Zaključak.** Na osnovu 30-godišnjih rezultata merenja, korišćenjem uvek aktuelne metodologije i opreme, na osnovu istraživanja stručnih lica i aktuelnih stručnih saznanja, zaključuje se da buka u životnoj sredini Novog Sada predstavlja dugotrajno prisutnu fizičku opasnost.

Ključne reči: gradovi; buka; životna sredina; faktori rizika; javno zdravlje; oprema i materijali; istorija medicine

Introduction

Noise is recognized as a physical hazard and if it is threatening the health and leading to diseases in the population, it is recognized as an environmental risk; in other words, environmental noise is a harmful sound created by human activities, including road, rail and air traffic noise and noise

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Abbreviations

WHO	– World Health Organization
EEA	– European Environment Agency
EPA	– Environmental Protection Agency
IPHV	– Institute of Public Health of Vojvodina
SEL	– sound exposure level
TNI	– traffic noise index
Lday	– noise level during the day
Levening	– noise level during the evening
Lnight	– noise level during the night
Lden	– noise level during the day, evening and night
LReqT	– rating equivalent continuous level
NMT	– noise monitoring terminal
LAeq	– equivalent continuous noise levels
LAmin	– minimum values of the average noise levels
LAmax	– maximum values of the average noise levels
L10, L50, L90	– average noise levels at selected intervals

originating from industrial plants [1]. Noise, or sound, is a wave of air pressure, and the human ear is sensitive to such waves in the range of 20 − 20.000 Hz. The speed of sound through the air is approximately 343 m/s. Sounds are emitted by natural (thunder, wind, for example) and artificial sources (human activity, mainly traffic and industry). Sounds are not limited to any one point in space, but are present all around the sound source, so we refer to a sound field in which the sound intensity or sound waves diminish with the increase of distance relative to the sound source, due to spreading and absorption. How do we hear sounds? Air vibration consequently causes eardrum vibration, which is then transmitted to the auditory nerve, and the nervous system translates the vibration into sound information. Sounds can be loud (a high amplitude wave) or quiet (a low amplitude wave); they can be broadband (a mix of audio information from a sound field) or tonal (when one audio component audibly stands out from general noise).

According to contemporary scientific insights of the World Health Organization (WHO), the European Environment Agency (EEA) and the Environmental Protection Agency (EPA), as well as researches conducted in our country [2−6] environmental noise is recognized as a factor that leads to anxiety, hearing disorders, sleep disturbances, cognitive disorders in children, and cardiovascular diseases [7], and is considered a stressogenic factor that affects human mental health as well [8]. Besides the above mentioned, environmental noise presents a challenge for modern urban planning, and certainly closely related human health and the issues of people's exposure to noise, and is unavoidable in all action plans and strategies for human health and environmental protection [9, 10]. Considering the fact that environmental noise is a contributing factor to the appearance of the above mentioned diseases, noise measurement and assessment of its impact on the health of the population has been in the focus of medical profession for a number of years. Data on the determined environmental noise levels collected for several decades that are at the disposal of public health institutes and institutions enable a detailed analysis and historical review of the environmental noise level trends [11].

The aim of this study is to present the history of environmental noise measurements in Novi Sad, together with the indicators, methods and standards used and to offer a review of the measurement results for the previous three decades.

ANoise level meter Type 2205 Brtiel & Kjasr. used in the period 1985–1989./*Merač zvuka tipa 2205 Brtiel i Kjasr, korišćen u periodu 1985–1989*

ANMT installed in Futoška Street, Novi Sad/*NMT postavljen u Futoškoj ulici, Novi Sad.*

A Briiel & Kjajr 4427 and an octave filter Briiel & Kjar 1625, used in the period 1990–2002/ *Briiel & Kjajr 4427 i oktavni filter 1625, korišćen 1990–2002*

A Briiel & Kjar type 2250, Brüel & Kjar type 3535-A protective case set (with the noise meter inside) and a Briiel & KjarOutdoor Microphone type 4952/*Briiel & Kjar tip 2250 i tip 3535-A zaštitno kućište (sa bukometrom unutar njega)*

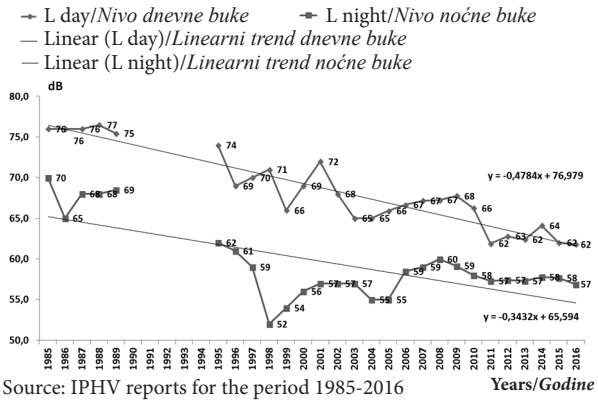
Figure 1. Noise monitoring equipment in Futoška Street, Novi Sad

Slika 1. *Oprema za monitoring buke u Futoškoj ulici u Novom Sadu*

Material and Methods

Based on the data available, the first noise measurements in Serbia were conducted in Belgrade in 1957, using a phonometer, General Radio Co [12], while environmental noise in Niš has been monitored since 1995 [13, 14]. The oldest available reports on the measurement of environmental noise in Novi Sad, stored in the archives of the Institute of Public Health of Vojvodina (IPHV) date back to April 1985.

Measurements of "communal noise" (commonly used terminology in the 80s and 90s) were carried out each month, three times a day (at 06:30 AM, 14:00 PM, and at 17:00 PM) on two measurement sites, in the course of a single day. Night-time measurements were conducted during September at 0:30 and 03:30 AM, on the same measurement sites as the day-time measurements. There were a total of 15 - 18 measurement sites, covering representative city areas. With minor changes (e.g. in 2010, night noise was measured four times a year - in spring, winter, summer, and autumn), this methodology was maintained until March 2011. The new history of measuring environmental noise in the City of Novi Sad



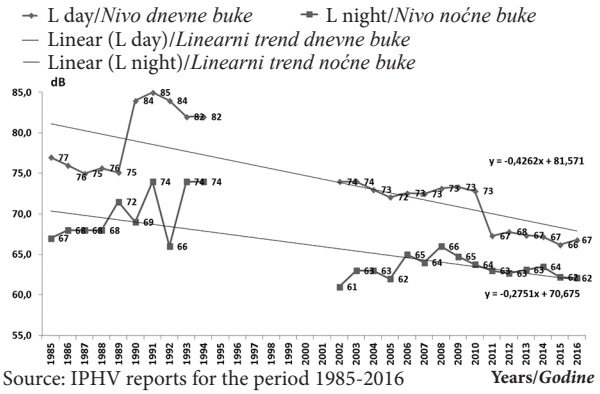
Source: IPHV reports for the period 1985-2016
Izvor: Izveštaji IZJZV za period 1985-2016
•data for1990-1994 are not available/•*podaci za 1990-1994 nisu dostupni*

Graph 1. Mean annual equivalent noise levels (1985 – 2010)/day/night time indicators (2011 – 2016) in leasure and recreational areas/hospital zone
Grafikon 1. *Srednje godišnje vrednosti ekvivalentnog nivoa buke (1985–2010)/ indikatora dnevne i noćne buke (2011–2016) u područjima za odmor i rekreaciju/ bolničkoj zoni*

started in April 2011. The 24-hour measurements have been conducted since then, because hardware and software development made it possible.

In regard to equipment used for measuring noise levels, records show that in the period 1985 – 1989, the Brüel & Kjær Sound Level Meter Type 2205 was used together with the Octave Filter Type 1613 by the same manufacturer, sampling 300 audio levels per each measurement, and a frequency analysis was done for each time of the day.

From 1990 to April 2002, the Brüel & Kjær Sound Level Meter Type 4427 was used, which sampled 64 sound levels per second, and generated data about Leq, L0, L10, L50, L90, L100, traffic noise



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Graph 2. Mean annual equivalent noise valuse (1985 – 2010)/ day/night time indicators (2011 – 2016) in business-residential areas
Grafikon 2. *Srednje godišnje vrednosti ekvivalentnog nivoa buke (1985–2010)/ indikatora dnevne i noćne buke (2011–2016) u poslovno-stambenim područjima*

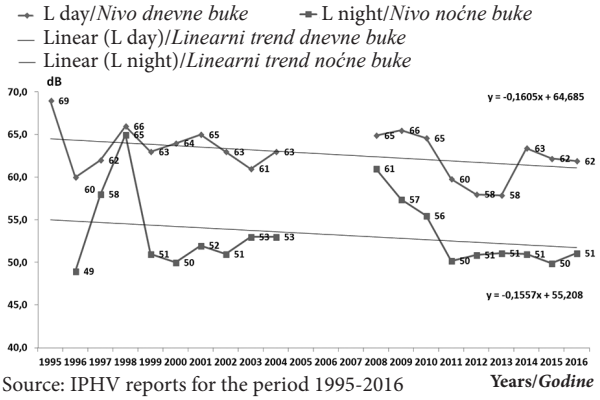
index (TNI) and short sound exposure level (SEL) (noise level in decibels that can produce a current sound event lasting one second). The microphone windscreen polyethylene foam cover was also used in order to prevent possible wind caused noise, as well as to protect the microphone from dirt, dust, rain or snowfall. From 1995, the Brüel & Kjær Octave Filter 1625 was used, as an addition to the Brüel & Kjær Noise meter 4427, for frequency analysis in the frequency range from 31.5 Hz to 8000 Hz.

From April 2002 to March 2009, the Brüel & Kjær 2260 was used, together with the 4231 type calibrator, condenser microphone type 4189, and the Software Noise Explorer Type 7815 Version 4.15. In 2005, the IPHV was certified for the first time, fulfilling the requirements of the JUS ISO 9001:2001 and JUS ISO 14001:1997 standards, and accredited in accordance with the requirements of the JUS ISO/IEC 17025 standard in 2010.

Since April 2009, the IPHV has been using a system for 24-hour noise level measurement and determination of the value of the basic environmental noise indicators (noise level during the day - L_{day}, noise level during the day, evening and night - L_{den}, noise level during the evening - $L_{evening}$, noise level during the night - L_{night}) and the supplementary noise indicator (rating equivalent continuous level -L_{ReqT}), which consists of: The Brüel & Kjær Noise meter type 2250, Brüel & Kjær type 3535-A (a protective case that acts as physical protection equipment), Brüel & Kjær Outdoor Microphone type 4952, BZ 5503 Utility Software and the Noise Explorer Type 7815 Software.

Since 2012, the IPHV has been using the Brüel & Kjær Noise Monitoring Terminal (NMT) 3639–E–103 with the accompanying Environmental Noise Management System Software Type 7843, which, is used only at two measurement sites: 121 Futoška Street and Partizanska Street, due to its immobility **(Figure 1)**.

The methodology of measuring environmental noise has always been prescribed by applicable national and international standards. The applicable regulation in the 1980s was the Rulebook on the allowed noise levels in the environment, Official Gazette SRS, No. 57/82. The regulations applied in the period 1992 to 2010 were: Law on Environmental Protection, Official Gazette of RS No. 66/91 [15], Rulebook on permitted environmental noise levels, Official Gazette of RS No. 54/92 [16], Methods for measuring environmental noise, Official Gazette of RS No. 54/92 [17], as well as standards for Measuring noise in the communal environment, SRPS U.J6.090 [18] and Acoustic Zoning, JUS U.J6.205 [19]. Since the 2010s, national standards have been harmonized with the European Directive 2002/49/EC [20]. Since then, the following have been in effect: Law on Public Health, Official Gazette of RS No. 72/2009 [21], Law on Environmental Noise Protection, Official Gazette of RS No. 36/2009 [22], Regulation on noise indicators, limit values, noise indicators assessment methods, annoyance and harmful effects of environmental noise, Official



Source: IPHV reports for the period 1995-2016
Izvor: Izveštaji IZJZV za period 1995-2016
•data for2005-2007 are not available/•*podaci za 2005-2007 nisu dostupni*

Graph 3. Mean annual equivalent continuous noise levels (1995 – 2010)/day/night time noise indicators (2011 – 2016) in residential areas
Grafikon 3. *Srednje godišnje vrednosti ekvivalentnog nivoa buke (1995–2010)/indikatora dnevne i noćne buke (2011–2016) u stambenim područjima*

Gazette No. 75/2010 [23], Rulebook on the methods of noise measurement, content and scope of the noise measurement report, Official Gazette of the RS 72/2010 [24], as well as the SRPS ISO 1996-1:2010 [25] and SRPIS ISO 1996-2:2010 [26].

The results of the measurements were presented differently in different periods. From 1985 to 2011, measurement results were shown as values of the equivalent continuous noise levels (L_{Aeq}), which was, in principle, also a rating equivalent continuous level (L_{ReqT}) due to representativeness of the duration of measurement, measurement conditions and choice of measuring sites. Reports also showed the minimum (L_{Amin}) and maximum values (L_{Amax}), as well as the average noise level in the selected interval, such as L_{10}, L_{50}, L_{90}.

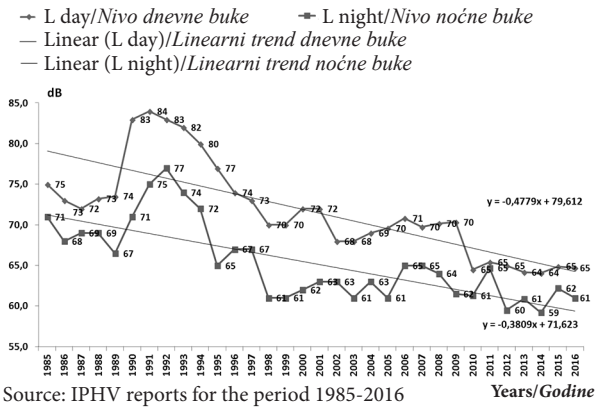
Since 2011, the values are determined by the basic noise indicators - daily, evening, night and overall noise (L_{day}, L_{den}, $L_{evening}$, L_{night}) (an indicator is a physical value that describes environmental noise, which is associated with adverse effects on human health), while the measurement sites are ranked by measured values in accordance with the European Directive.

There is a question of comparing different methodologies. It is important to point out that comparison between the "old" (rating equivalent continuous level) and "new" (basic noise indicators) noise indicators will be reported in a new paper, and the authors of this paper intend to do it in the future. The task, due to complexity, exceeds the historical survey of noise measurements during 30 years in Novi Sad.

Results

From the abundance of available data collected during the noise measurement in Novi Sad in the period 1985 – 2016 (**Graphs 1**–**5**), this paper presents data only from five (5) measurement sites, which were used both in the 1980s and in the last decade, and are not only representative measurement sites, but representative zones for a longer period of time. In retrospect, while keeping in mind the defined acoustic zones of Novi Sad, the measurement sites are shown in accordance with the purpose of the areas as defined by the Spatial Plan of the City of Novi Sad [26] and the City Noise Measurement Program [27, 28]. In the period 1985 – 2013, the Institute determined environmental noise in Novi Sad at the network of measurement sites, designed in the Institute. Measurement sites in the City of Novi Sad presented in the study and classified according to the purpose of the given area were: Novo Naselje in Residential Areas, Bulevar oslobođenja/across the "Dnevnik" and Bulevar Mihajla Pupina in Zone of City Roads, Salajka (Partizanska Street) in Business-residential Areas, Close to hospital and Towards Sports Center Sajmište in Leisure and Recreation Areas/Hospital Zone, and Petrovaradin (vicinity of Elementary School Jovan Dučić) in School Zone.

The legal environmental noise limit values are: 50 dB for day/evening and 40 dB for night in Leisure and Recreation Areas/Hospital Zone; 50 dB for day/evening and 45 dB for night in School Zone; 55 dB for day/evening and 45 dB for night in Residential Areas; 60 dB for day/evening and 50 dB for night in Business-residential Areas; 65 dB for day/evening and 55 dB for night in Zone of City Roads. The environmental noise limit values have been exceeded in all decades and in all acoustic zones in Novi Sad, regardless of the methodology or measuring equipment used, which indicates that noise monitoring and actions for noise reduction should be the priority for the community.



Source: IPHV reports for the period 1985-2016
Izvor: Izveštaji IZJZV za period 1985-2016

Graph 4. Mean annual equivalent continuous noise levels (1985 – 2010)/day and night time noise indicators (2011 – 2016) in the zone of city transportation
Grafikon 4. *Srednje godišnje vrednosti ekvivalentnog nivoa buke (1985–2010)/indikatora dnevne i noćne buke (2011–2016) u zoni gradskog saobraćaja*

The Linear trends for daytime and nighttime noise, based on thirty years of monitoring results at the measuring sites, show a decline (**Graphs 1 – 5**). However, this does not mean that there is a decrease in environmental noise. In fact, historical data from 1985 to 2016 show that the minimum and maximum values are getting closer to each other, which indicates that the noise in the city is "evenly distributed" and that it is omnipresent, which has been corroborated by studies of IPHV experts [29, 30].

Discussion

What has changed since the 1980s in regard to measuring environmental noise and the interpretation of the noise impact on human health?

In our country, over the past decades, only public health and scientific institutions have been concerned with environmental noise measurement. However, gradual changes of regulations and their interpretation, together with a developing need for monitoring environmental factors, have led to the fact that monitoring environmental noise is no longer the sole responsibility of healthcare institutions, although there is a strong public feeling that it primarily still is. New legislative solutions [31] "are returning" noise to the sphere of public-health issues, in regard to interpretation of the impact of noise on human health.

Secondly, the terminology has changed. Although it is referred to as "environmental noise" today, the term "communal noise" is being "reinstituted" through the new version of the SRPS ISO 1996-1:2016 standard, which defines "noise" in the community ("community noise"). The reports have, of course, changed over time, and the quality system and the National Accreditation Body (NAB) have contributed to the advances in measurement and a greater reliability of measurement results.

Thirdly, measurement technologies have developed, which has been described above in detail.

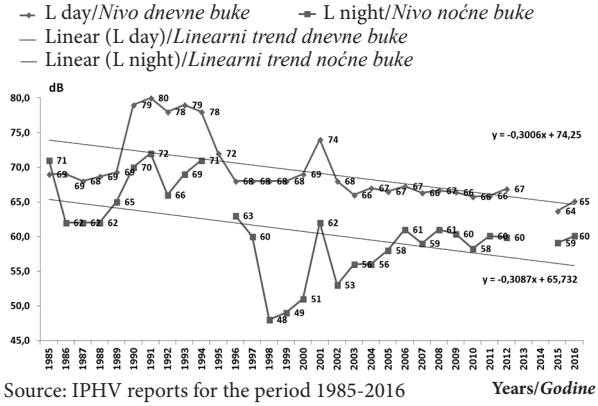
Fourthly, the contemporary era, the concept of general availability of data, the use of open source, as well as the fact that anyone can measure noise using a smartphone (such measurements are not reliable, but they offer an insight into the approximate noise level) and to share the measurement information with others through various open information systems, have made the issue available and interesting to the general public. Saying that, for example, the noise level measured at a certain place is 70 dB, is becoming less interesting for the public, so data are displayed in the form of various indexes (for example, by red colour, an index type "5 of 7" or an angry "emoji" face, etc.). The future will definitely see an increase in additional environmental noise monitoring - by the noise modelling method, as technological progress and an increasing accuracy of models are followed by a development of new softwares.

Today, there are software solutions that generate noise maps, for example, "Lima", which is in possession of IPHV since 2011. The software produces a noise map based on the entered data on the measured noise levels.

What has not changed since the 1980s in regard to measuring environmental noise and the interpretation of the noise impact on human health?

The sources of noise have remained the same: traffic, particularly road traffic noise, human activities, and industrial noise. The following passage from a report dating back to 1990 shows that when environmental noise is concerned, not much has changed over time: "In urban areas, there are three main sources of noise: traffic, daily living activities, and the industry. The most important source of noise in inhabited places is traffic, as this type of noise accounts for about 80% of the overall noise. The intensity of traffic noise in inhabited areas is affected by: the number and types of vehicles, use of sound signals, speed of vehicles, street width, arrangement of buildings and number of floors, street greenery, as well as the time of the day and year [32]."

The purpose of measuring noise levels has remained the same - to monitor the effect of noise on human health (particularly the contribution of noise to cardiovascular diseases) and the study of auditory and extra-auditory effects of noise. Back in 1990, experts from the IPHV wrote in their reports about "health aspects of communal noise: The main purpose of determining (measuring) the intensity of communal noise is its impact on human health. The effects of noise depend on the intensity, frequency and duration of noise, sensitivity to noise and changes in noise [32]."



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Izvor: Izveštaji IZJZV za period 1985-2016
•data for1995, 2013-2014 are not available/•*podaci za 1995, 2013-2014 nisu dostupni*

Graph 5. Mean annual equivalent continuous noise levels (1985 – 2010)/day and night time noise indicators (2011 – 2016) in the school zone

Grafikon 5. *Srednje godišnje vrednosti ekvivalentnog nivoa buke (1985–2010)/indikatora dnevne i noćne buke (2011–2016) u školskoj zoni*

Proposals for reducing noise are still the same, and the public is still interested in this issue. According to historical data, proposals for noise reduction included the following: "Due to adverse effects of noise on human health, it is necessary to reduce the intensity of communal noise. Primarily, town zoning needs to be carried out in terms of traffic rerouting, particularly heavy vehicle traffic, into the parts outside the residential zones or outside of the town. Followed by proper urban solutions, in terms of building streets of sufficient width and planting greenery, which can reduce the intensity of noise up to 10–15 dB (A). In apartment buildings, by proper architectural solutions in terms of room layout (putting rooms where people spend more time on the side opposite the roads). By constructive solutions, in terms of the choice of building materials and methods of construction, street noise transfer into homes and work spaces can be affected. By administrative solutions – introduce time limits for driving for all vehicles or heavy vehicles particularly on the roads vulnerable to noise [32]."

Conclusion

Based on the 30 years' measurement results, collected always using current, up-to-date methodology and equipment, based on the research of the experts of the Institute of Public Health of Vojvodina and current scientific knowledge, it is concluded that the environmental noise in Novi Sad presents a long-lasting physical hazard.

Taking preventive measures, ranging from those in the field of urban planning, through transportation to individual measures, in particular in the areas of the city with sensitive population (kindergartens, schools, healthcare facilities), should be considered as one of the priorities of the urban development of the City of Novi Sad. It is important to point out that comparison between the "old" (rating equivalent continuous level) and "new" (basic noise indicators) noise indicators will be studied in another paper, and the authors of this paper intend to do it in the future.

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