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NOISE INDUCED HUMAN POPULATION ANNOYANCE IN URBAN ENVIRONMENT OF CITY OF NOVI SAD (SERBIA)

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ABSTRACT. The objective of this paper is to estimate percent of the human population in the City of Novi Sad (CNS) annoyed by road traffic noise according to two methods (ISO 1996-1: 2016, and National norm from 2010). 24-hour noise measurements data in the area of the city center and city roads in the CNS from 2012 to 2016 are obtained from the Institute of Public Health of Vojvodina (IPHV). Both methods show similar results, although with varying precision within the different noise range. Night noise stands out as a problem due to the fact that the expert recognize it as a significant factor responsible for the non-auditory effects of noise on human health and because the results of measurements of the IPHV confirm that the night-time noise is increased by 98% of measurements in the city traffic area.

Keywords: environmental urban traffic noise, annoyance, human population.

INTRODUCTION

Noise is an of pollution forms. It can be defined as subjectively unpleasant or unwanted sound. Based on the European Noise Directive, "environmental noise" shall mean unwanted or harmful outdoor sound created by human activities, including noise emitted through transport, road traffic, rail traffic, air traffic, and from sites of industrial activity such as those defined in Annex I to Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control (Directive 2002/49/EC).

The World Health Organization (WHO), the European Environment Agency (EEA) and the United States Environmental Protection Agency recognize environmental noise as a factor that causes human population annoyance, hearing impairment, sleep and repose disturbance, cognitive impairment in children and cardiovascular diseases (NUGENT *et al*., 2014). It is also considered to be a stressful factor that can affect people's mental health, because when exposed to noise, people feel anxious and uncomfortable, which is more pronounced in introverted, neurotic and chronically ill persons (BELOJEVIC *et al.,* 2001). Also, noise has been recognized as a risk factor for myocardial infarction because, as a stressor, by activating the hormonal system, it potentiates all those most significant risk factors for this disease: hypertension, hyperglycemia, hyperlipidemia and hypomagnesemia (MASCHKE *et al.,* 2000). Recent studies

also point to the significant role of long-term noise exposure, especially night noise ≥ 55 dB in the pathogenesis of male sterility, and the relationship between noise and breast tumors, brain strokes, type 2 diabetes and obesity (MIN *et al.*, 2017; BELOJEVIĆ and PAUNOVIĆ, 2016).

The night-time noise to which humans are exposed in the environment is designated as particularly "hazardous" for human health by the WHO which provides specific frameworks for identifying values that are regarded as hazardous to human health (HURTLEY, 2009).

Noise annoyance is the feeling of anger, dissatisfaction, discomfort, or the feeling that noise interferes with one's thoughts, feelings and current activities (VAN KAMP, 2011). Noise annoyance is subjective - individual differences are large and depend on both the noise level and several non-acoustic factors. One of the challenges that lie ahead of hygiene as a branch of medicine is to determine, based on available data, how much of the human population is annoyed by environmental noise. Hereof, the distinction is made between population annoyance by noise throughout the day (referring to the percent of the population interfering with noise during daily activities) and the population annoyance by night noise (referring to the percent of the population whose sleep is disturbed or interrupted by noise).

The objective of the paper is to estimate, based on data collected over several years on noise level measurements in the urban environment in the City of Novi Sad (the area of the city center and city roads), by using different methodological approaches, the percent of the human population annoyed by road traffic noise.

MATERIAL AND METHODS

Novi Sad is the second-largest city in Serbia in terms of the number of citizens (human population) and area. It is the largest city in the Autonomous Province of Vojvodina, the administrative, cultural, scientific, health and political center, and it is a university city and a school center, as well. According to the results of the 2011 census, there were 341,625 inhabitants in the administrative territory of Novi Sad, where 250,439 live in the very City of Novi Sad and 277,522 in the urban area that constitutes the City of Novi Sad. Hence, about 300,000 people live in the urban part of the city and represent the population that will be treated in the paper, which is in addition to urban noise also exposed to other environmental risk factors (JEVTIĆ, 2011).

Figure 1. Map of noise measuring points in the "zone of the city center and city roads" in Novi Sad: 1 – Telep, Vršačka 28; 2 – Stari grad, Bulevar Mihajla Pupina 16; 3 – Stari grad, Zmaj Jovina St. 3/1.

Institute of Public Health of Vojvodina has been conducting measurements of environmental noise at measuring sites in Novi Sad since 1985 (ŽIVADINOVIĆ *et al.*, 2018). For the period 1985–2010, data are available in the form of mean equivalent of daily/monthly/annual values, and since 2011 the measurements have been exclusively on a 24-hour basis. The paper uses data obtained in the "zone of the city center and city roads", on the three measuring points (1 – Telep, Vršačka st. 28; 2 – Stari grad, Bulevar Mihajla Pupina 16; and 3 – Stari grad, Zmaj Jovina Street 3/1; Figure 1) during the five years period 2012–2016.

There are two ways to determine the approximate percentage of the human population annoyed by noise. The first way is to calculate the percent of the annoyed population based on the determined values of the day-evening-night noise indicator (L_{den}) and the night-time noise indicator (L_{night}) in a certain area, by equation, i.e. modeling. The other way of determining the percent of the population annoyed by noise is defined by the ISO/TS 15666:2013 standard and expert knowledge (ŽIVADINOVIĆ, 2018), whereby the data is generated by surveying the human population, i.e. the persones respond to the question if and which kind of noise disturbs them. Both ways have numerous limitations, but they still provide an insight into how much environmental noise affects people's lives.

According to the 2010 National norm (ANONYMOUS, 2010) equations for calculating the percent of the human population affected by road, rail and air traffic noise are:

During the day-evening-night time:

- road traffic noise

$$\% A = 1.795 \cdot 10^{-4} \cdot (L_{den} - 37)^3 + 2.110 \cdot 10^{-2} \cdot (L_{den} - 37)^2 + 0.5353 \cdot (L_{den} - 37) \quad (1)$$

$$\% HA = 9.868 \cdot 10^{-4} \cdot (L_{den} - 42)^3 - 1.436 \cdot 10^{-2} \cdot (L_{den} - 42)^2 + 0.5118 \cdot (L_{den} - 42) \quad (2)$$

During the night-time:

- road traffic noise

$$\% A = 13.8 - 0.85 L_{eq} + 0.01670 \, L_{night}^2 \quad (3)$$

$$\% HA = 20.8 - 1.05 L_{eq} + 0.01486 \, L_{night}^2 \quad (4)$$

whereby: % A – percent of annoyed (% A) people in the population; % HA – percent of highly annoyed (% HA) people in the population.

The novelty introduced by the standard is the term community tolerance level (L_{ct}), which indicates the level of noise that is projected to cause 50% of the community population to be highly annoyed. The value of L_{ct} must be proposed, empirically established by decision-makers and relevant professional services – logically, it should be public health, promoting hygiene as a science (ISO 1996-1: 2016).

Equations for determining the prevalence of a population highly annoyed (P_{HA}) by the road traffic noise, according to this standard (ISO 1996-1: 2016), are in function L_{dn} (equation 1), or function L_{den} (equation 2):

equation 1: $$P_{HA} = 100e^{-\left(\frac{1}{10^{0,1(L_{dn}-73dB)}}\right)^{0,3}} \quad (5)$$

equation 2: $$P_{HA} = 100e^{-\left(\frac{1}{10^{0,1(L_{den}-73,6dB)}}\right)^{0,3}} \quad (6)$$

If the expert public decides that L_{ct} = 78.3 dB (example from the standard) is for road traffic noise, then the P_{HA} by road traffic noise is read from the table taken from ISO 1996-1: 2016 (Table 1).

These data indicate the interval at which 95% of the emerging scenarios for environmental noise should be. For example, if L_{den} is predicted to be 53 dB on the new road then the table can predict that the P_{HA} is 1.6% and 95% of such communities (19 out of 20)

would have a high vulnerability P_{HA} by noise ranging from 0.0% to 18.3%, and one in 20 communities would be out of this range (HURTLEY 2009).

Table 1. The prevalence of Novi Sad Citz human population highly annoyed and corresponding 95% interval of prediction as function L_{dn} or L_{den} for road traffic noise.

L_{dn} or L_{den} (dB)	**Upper 95% prediction interval (%)**	**Lower 95% prediction interval (%)**	**Prevalence of population highly annoyed by using L_{dn} (%)**	**Prevalence of population highly annoyed by using L_{den} (%)**
45	8.2	0.0	0.1	0.1
46	9.1	0.0	0.2	0.1
47	10.2	0.0	0.2	0.2
48	11.3	0.0	0.4	0.3
49	12.5	0.0	0.5	0.4
50	13.8	0.0	0.7	0.6
51	15.2	0.0	1.0	0.9
52	16.7	0.0	1.4	1.2
53	18.3	0.0	1.9	1.6
54	19.9	0.0	2.4	2.1
55	21.7	0.0	3.1	2.7
56	23.5	0.0	3.9	3.4
57	25.5	0.0	4.9	4.3
58	27.5	0.0	6.0	5.3
59	29.5	0.0	7.2	6.5
60	31.7	0.0	8.6	7.7
61	33.9	0.0	10.1	9.2
62	36.2	0.0	11.8	10.8
63	38.5	0.0	13.6	12.5
64	40.8	0.0	15.5	14.4
65	43.2	0.0	17.6	16.3
66	45.7	0.0	19.8	18.4
67	48.1	0.0	22.0	20.7
68	50.6	0.0	24.4	22.9
69	53.0	0.0	26.8	25.3
70	55.4	0.0	29.2	27.7
71	57.8	0.0	31.7	30.2
72	60.2	0.1	34.3	32.7
73	62.6	0.1	36.8	35.3
74	64.9	0.1	39.3	37.8
75	67.1	0.1	41.9	40.3

NOTE: These values are for L_{ct} = 78.3 dB, total L_{ct} for road traffic noise.

Comparing the two ways to determine the approximate percentage of the persons annoyed by noise was done by Pearson correlation with a coefficient of determination (r^2 x 100=% of the variability of two methods), ANOVA, independent T-test and linear regression as well. All statistical analyses were done by SPSS software (SPSS for Windows, ver. 17, 2008).

RESULTS

The percent of the human population annoyed by road traffic noise was determined based on the 53 data set of 24-hour noise measurements over the 2012-2016. time period.

Determined values of basic noise indicators (day-time noise L_{day}, evening-time noise $L_{evening}$, night-time noise L_{night} and day-evening-night time L_{den}) in the environment of the City of Novi Sad in the "zone of the city center and city roads", i.e. on the three measuring points, are shown graphically (Charts 1–3).

Based on 53 data set of 24-hour environmental noise measurements over the five-year period 2012–2016, L_{day} values determined ranged from 56.3–68.5 dB; $L_{evening}$ ranged from 53.2–68.4 dB; L_{night} ranged from 54,8–65,0 dB; L_{den} ranged from 61,8–71,2 dB. In the aforementioned period, in relation to the national norm, increased were: the day-time noise indicator in 23%, evening-time noise indicator in 11% and night-time noise indicator in 98% of measurements (Table 2).

Table 2. Statistical data processing and consistency of values of basic noise indicators (L_{day}, L_{den}, $L_{evening}$ and L_{night}) in the environment of the City of Novi Sad with boundary values on three measuring points in the "zone of the city center and city roads" during the period 2012–2016.

	L_{day} ** (dB)	**$L_{evening}$** (dB)**	**L_{night} ** (dB)**	**L_{den} *** (dB)**
Number of measuring	**53**	**53**	**53**	**53**
Minimal value	56.3	53.2	54.8	61.8
Maximal value	68.5	68.4	65.0	71.2
Middle value	**64.1**	**63.1**	**60.3**	**68.0**
Standard deviation	2.6	2.9	2.0	1.5
Number of measurements with limit exceeded *	12	6	52	---
Percent of measurements with limit exceeded *	22.64	11.32	98.11	---
Number of measurements without limit exceeded *	41	47	1	---
Number of measurements without limit value exceeded for noise indicator *	77.36	88.68	1.89	---

*City center, craft, trade, administrative-governing zone with flats, zone along highways, main and city roads (Annex 2, Table 1, Regulation on noise indicators, limit values, methods for evaluating noise indicators, disturbance and adverse effects of noise in the environment, Official Gazette no. 75/2010); / **the limit values are 65 dB for day and evening, i.e., 55 dB for night;**

**The reference time interval for the day-time is 06:00 – 18:00, for the evening-time 18:00 – 22:00 and for the night-time 22:00 – 06:00, in terms of national norms;

***There is no national norm for L_{den}.

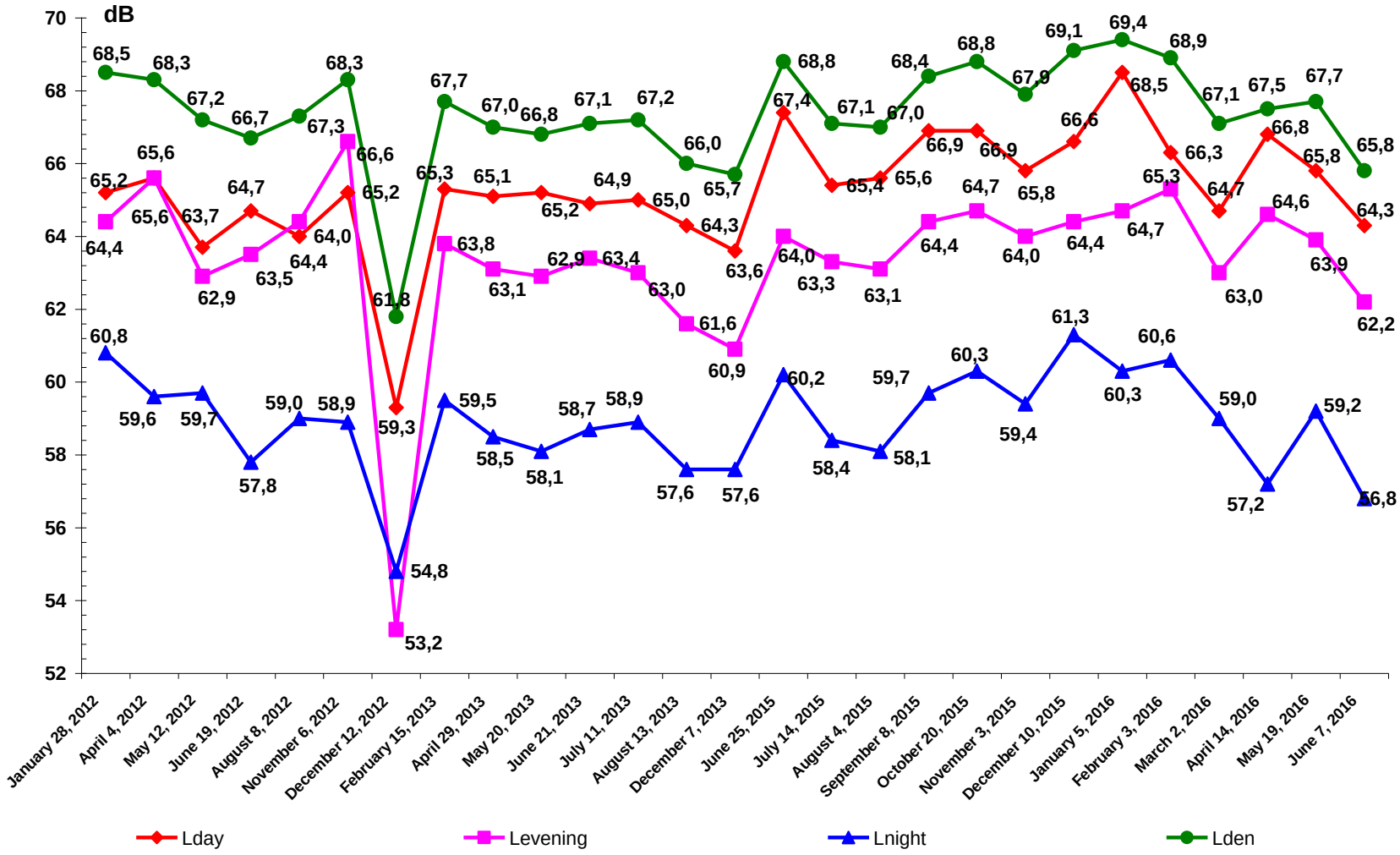

Chart 1. Values of basic noise indicators (L_{day}, $L_{evening}$, L_{night} and L_{den}) on the measuring point 1 in the "zone of the city center and city roads" of the City of Novi Sad during the period 2012–2016.

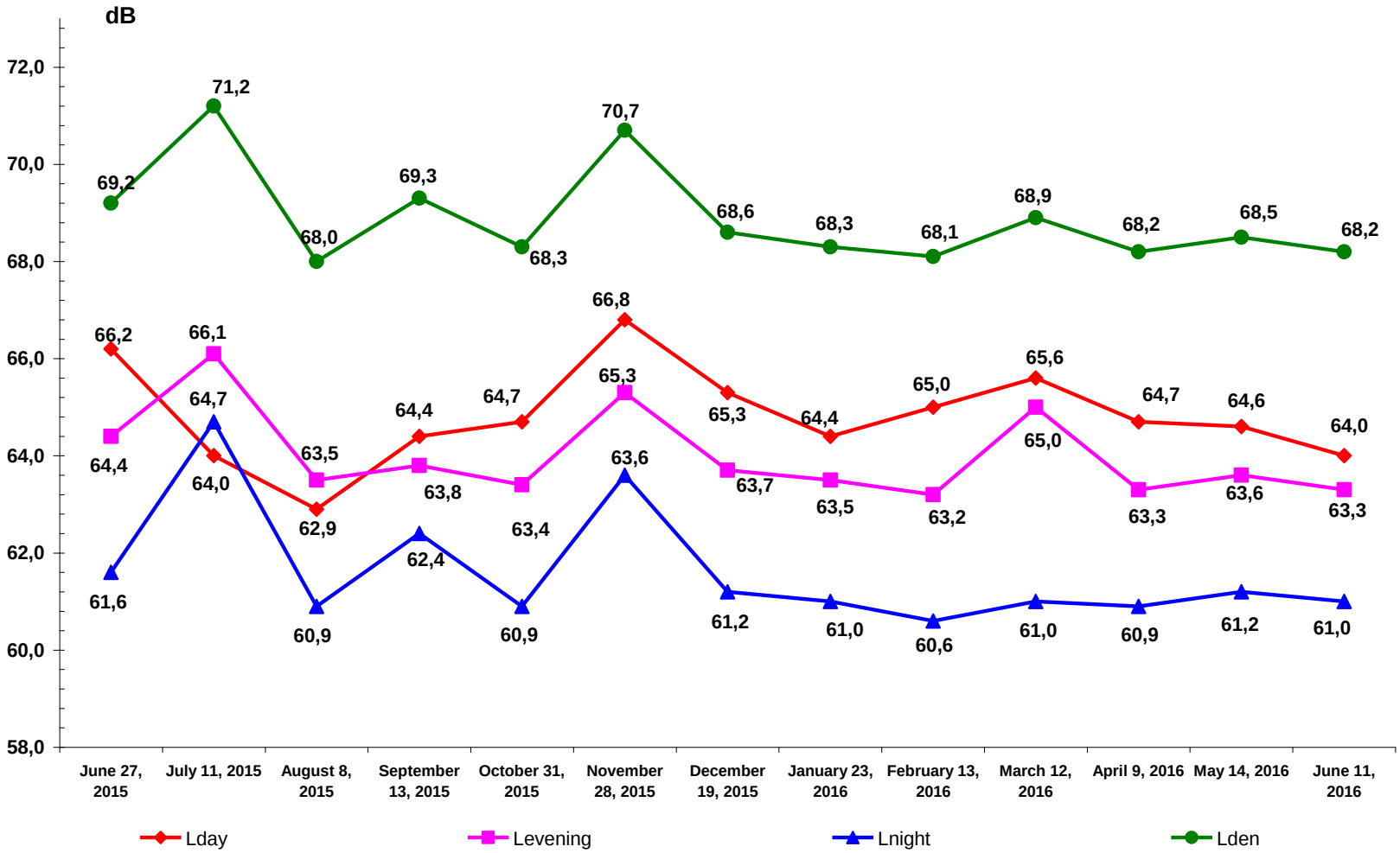

Chart 2. Values of basic noise indicators (L_{day}, $L_{evening}$, L_{night} and L_{den}) on the measuring point 2 in the "zone of the city center and city roads" of the City of Novi Sad during the period 2012–2016.

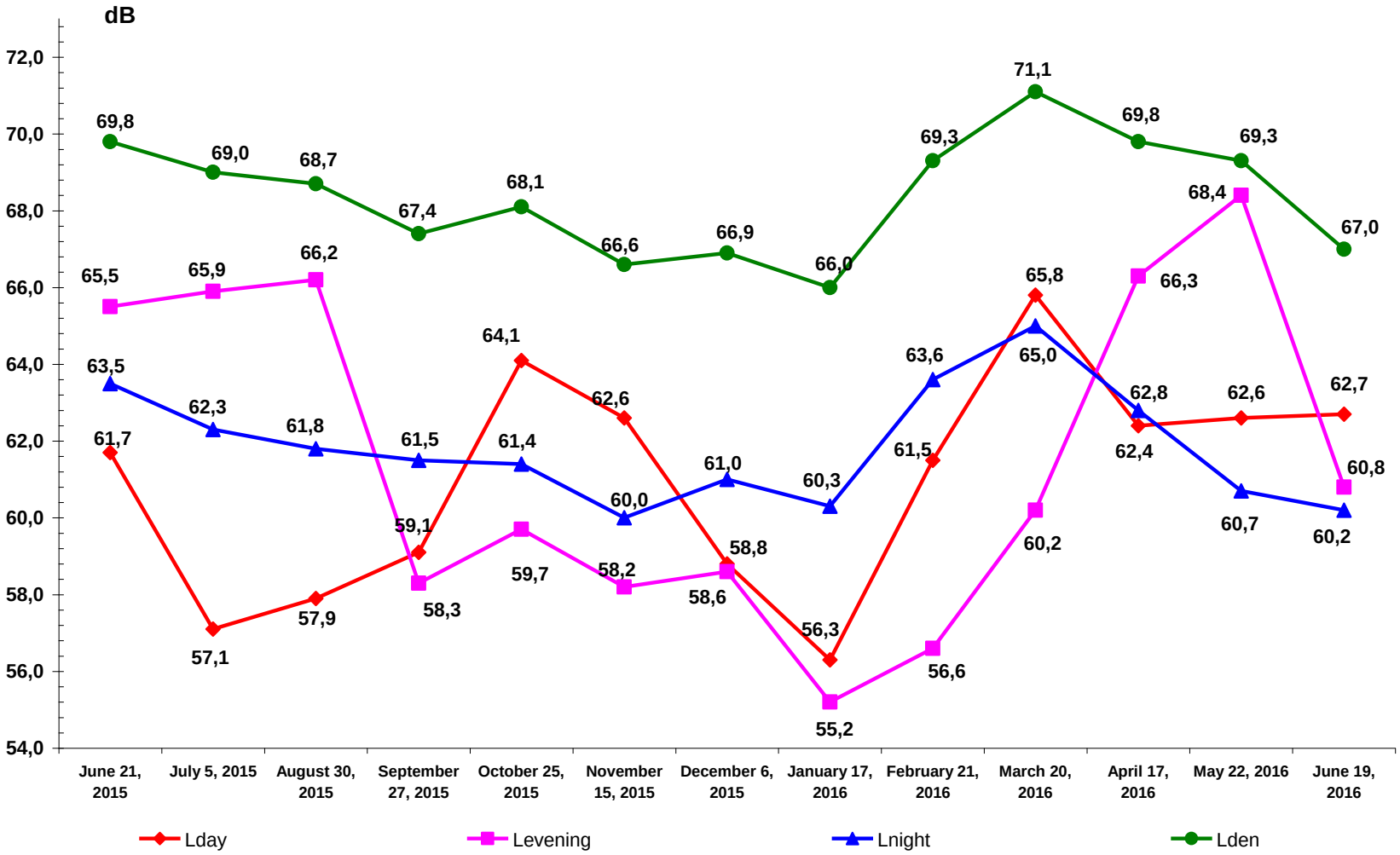

Chart 3. Values of basic noise indicators (L_{day}, $L_{evening}$, L_{night} and L_{den}) on the measuring point 3 in the "zone of the city center and city roads" of the City of Novi Sad during the period 2012–2016.

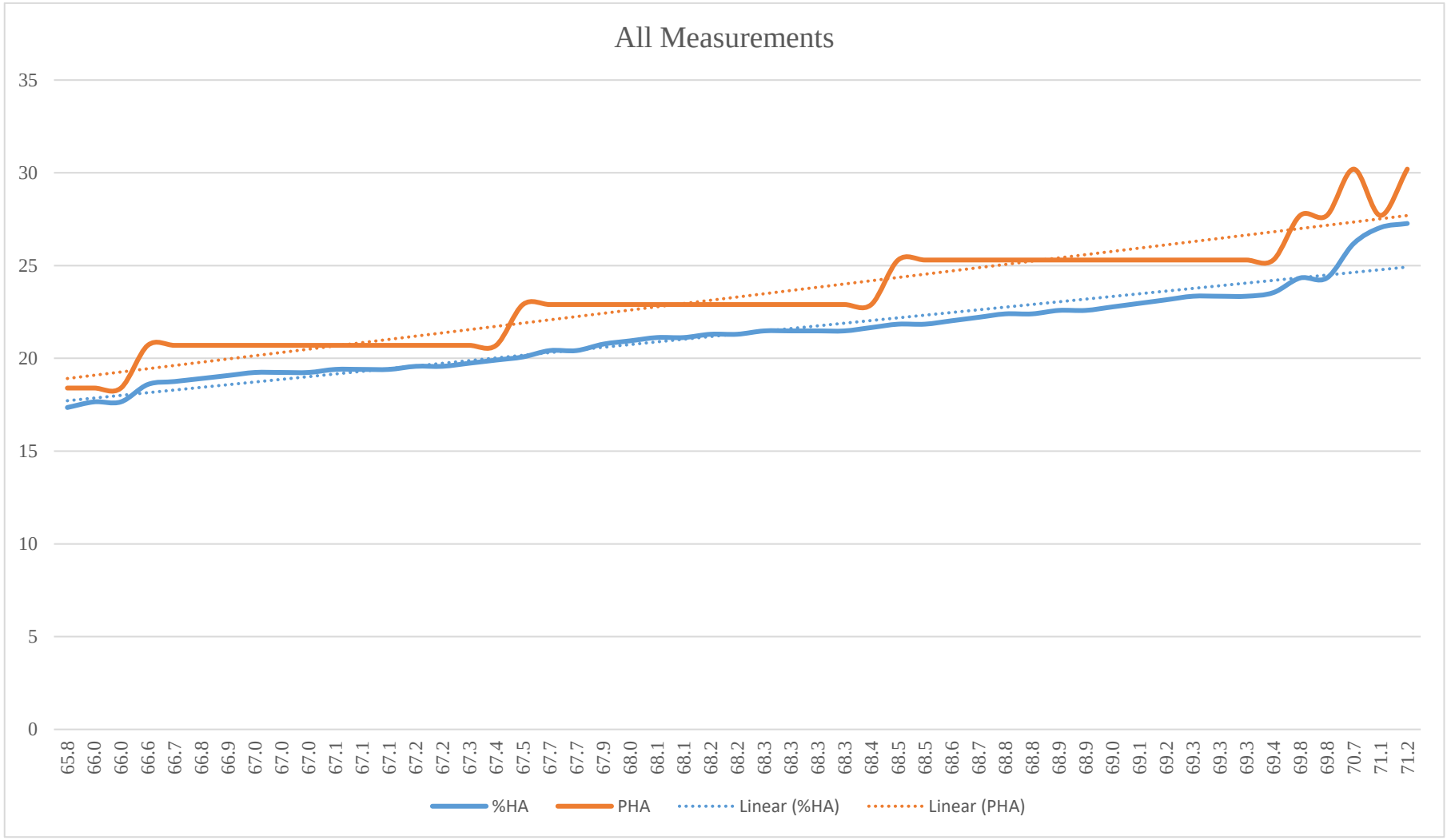

Chart 4. All measurements – linear trend % HA and PHA.

Compared to the middle value of L_{den} in the area of the city center and city roads of the City of Novi Sad during the five-year period 2012–2016, the estimated percent of the population highly annoyed by noise (%HA) of road traffic during the day-time was 21%, and the estimated percent of the population highly annoyed by noise (%HA) during the night-time (the estimated percent of the population whose sleep was disturbed by the noise of road traffic during the night) was 12% (Table 3).

Table 3. Percent of human population annoyed by road traffic noise in the area of the city center and city roads of the City of Novi Sad during the five-year period 2012–2016.

L_{den} */dB	% HA
68.00	**21**
L_{night} */dB	% HA
60.30	**12**

* middle five-year value for the zone defined by the purpose of the area;
% HA – percent of human population highly annoyed by noise
– methodology prescribed by national norms.

If compare the calculated %HA with PHA in relation to the middle value L_{den} during five-years period 2012–2016, the following values shown in Table 4 are obtained.

Table 4. Determination of prevalence of Novi Sad human population highly annoyed by methodology according to ISO 1996-1: 2016.

Zone of the City of Novi Sad by purpose of space	L_{den} * dB(A)	PHA
"Zone of city center and city roads"	68.0	22.9% (ranging 0%–50,6%)

* middle five-year value for the zone defined by the purpose of the area;
PHA – prevalence of population highly annoyed – methodology prescribed by the standard in the adoption phase.

Table 5. Correlations (% HA vs. PHA).

		L_{den}*	% HA*	PHA*
L_{den}	Pearson Correlation	1	0.988**	0.978**
	Sig. (2-tailed)		0.000	0.000
% HA	Pearson Correlation	0.988**	1	0.970**
	Sig. (2-tailed)	0.000		0.000
PHA	Pearson Correlation	0.978**	0.970**	1
	Sig. (2-tailed)	0.000	0.000	

*N (53); **Correlation is significant at the 0.01 level (2-tailed).

By comparing the values of PHA with the values of % HA, it was determined that PHA is slightly lower than % HA at lower L_{den} values, but as L_{den} increases, the PHA and % HA are more and more approaching to each other, i.e., are getting harmonized. Nevertheless, % HA is in the range between the lower and upper 95% confidence intervals for PHA. The new standard is obviously more flexible with respect to determining the percent of the human population affected by noise and envisages a number of different "scenarios".

Statistical data processing shows the statistically significant positive correlation of % HA and PHA, which means the correlation of PHA and % HA for environmental noise annoyance assessment is 0.97 (for 5 years), ie. the coefficient of determination is r^2=0.873. The linear change of % HA and PHA is 87.3%, and this difference of almost 13% means that % HA

and also PHA are applicable for environmental noise annoyance assessment over a long period of time such as a five years period. In addition, the ANOVA shows a statistically significant difference between PHA and % HA, if the results of all individual measurements over a long time period are compared each other, because the linear regression equation shows that 92.2% of the variability of results can be explained using % HA, while using PHA can explain 89.2% of the variability (Tables 5, 6; Chart 4).

Table 6. Comparing the two methods (% HA vs. PHA) – all measurements from three measuring points shown separately.

Methods	Measuring points	Mean	95% Conf. Interval (lower bound)	95% Conf. Interval (upper bound)	Min	Max	*p* value
PHA	1	21.6704	20.4454	22.8953	10.80	25.30	0.006
	2	24.9462	23.3766	26.5157	22.90	30.20	
	3	23.7231	21.7887	25.6575	18.40	27.70	
% HA	1	19.9259	18.9890	20.8629	12.00	24.00	0.005
	2	22.4615	21.2627	23.6604	21.00	27.00	
	3	21.6923	20.1053	23.2794	18.00	27.00	
L_{den}	1	67.3741	66.7852	67.9629	61.80	69.40	0.005
	2	68.8846	68.2759	69.4933	68.00	71.20	
	3	68.3846	67.4685	69.3007	66.00	71.10	

DISCUSSION

Based on the results, the population of the City of Novi Sad citizens is exposed to the night-time noise from 55 to 65 dB, i.e. the total noise from 62 to 72 dB. For the sake of comparison, an estimated 113 million people are affected by long-term day-evening-night traffic noise levels of at least 55 dB (PERIS, 2020).

Furthermore, more than 30% of the European human population is exposed to night-time noise higher than 55 dB (Петрушић, 2017). Based on the comparison of publicly available data for the City of Belgrade for 2016 with five-year data for the City of Novi Sad for the period 2012-2016. and with data for the City of Niš for 2017 and 2018 (ANONYMOUS, 2018) it can be seen that in the zone of Belgrade urban roads, the daily noise level was in the range 54-69 dB (in Novi Sad 56-69 dB), and night one ranged 48-68 dB (in Novi Sad 54-65 dB) / on Niš Boulevard Dimitrija Tucovića the daily noise indicator is 70 dB, and night 65 dB.

Based on the publicly available data, it can be estimated that in these areas of Belgrade, % HA is 6-23% during the day and 5-18% during the night, while in Niš % HA is 25% during the day and 15% during the night. The presented data confirm that the level of day and night noise is in the same range in the observed urban areas of Novi Sad, Belgrade and Niš, and therefore it can be considered that the percent of noise annoyed human population in the City of Novi Sad, Niš and Belgrade is in the same wider range. This assumption is confirmed with the results of this study, where is the range of % HA from 12% to 21%.

LARES study (NIEMANN and MASCHKE, 2004) is a large-scale study that examined housing conditions in European cities and the population's exposure to noise in apartments, especially the noise originating from traffic and neighborhood. One of the main conclusions is that noise leads to sleep disorders, that the human population is also disturbed by noise originating from traffic and noise originating in the neighborhood, and that the established effects of noise on health are independent of socioeconomic status and living conditions.

The thesis confirmed that there is a cause-effect relationship expressed in the three steps: health - chronic noise exposure - increased morbidity. With adults (18-59 years old) who are highly annoyed by noise, relative risks for cardiovascular, respiratory and musculoskeletal disorders as well as for depression are significantly increased. People over 60 years of age who are highly annoyed by noise respond less than adults, except for stroke. When it comes to children, the effects of noise should be viewed primarily in relation to the respiratory system. The number of people affected by noise-induced sleep disorders is bigger (23.3%) than the number of highly annoyed people (12.4% by neighborhood noise, 14.4% by traffic noise). Therefore, special attention should be paid to nighttime exposure to environmental noise.

Given that noise annoyance is a factor that affects human health, the WHO highlights the appropriate recommendations. In its new publications, the WHO even recommends reducing the noise level produced by the road traffic to below 53 decibels (dB) L_{den}, because the total noise above this level is associated with health side effects, ie it recommends reducing the noise level produced by road traffic during the night to below 45 dB L_{night}, because night noise above this level is associated with side effects on sleep (ANONYMOUS, 2019).

The paper presents two methods for estimating environmental noise annoyance. Estimates were made using current professional literature and long-term noise measurements own data of IZZZV. The significance of the previously presented results is that they are based on real, measured long-term data, stratified according to acoustic zones. This allows for representativeness in terms of assessing the impact of noise levels on the health of the human population, expressed through annoyance.

Additionally, results confirmed that ISO 1996-1: 2016 compared to national law is more flexible with respect to determining the percent of the human population affected by noise and envisages a number of different "scenarios". Moreover, the standard covers a wider range of variability in the assessment of human population annoyance based on measured environmental noise. This is valuable if the importance of annoyance is taken into account. Although in modern times modeling is used instead of measurement, and low-cost sensors instead of expensive laboratory equipment (SEVILLANO *et al.*, 2016; PICAUT *et al.*, 2020), such research indicates the importance of "real" monitoring to collect data on environmental risk factors that affect human health.

CONCLUSION

Noise is a pollution form, capable to initiate many of human health rections. The paper discusses and analyzes various methodological approaches for determining human population annoyance by environmental noise, as well as perennial levels of environmental noise in the City of Novi Sad (Vojvodina, Serbia). Based on the conducted research, the following can be concluded:

- The use of both methods described in this paper determines the percent of the human population annoyed by environmental noise that is alarming and worrying, and thus requires the reaction of the expert public. By using equations/models, it is concluded that more than 20% and more than 10% of the human population is disturbed by noise during the day or nighttime respectivelly.
- Both PHA and % HA can be used for environmental noise annoyance assessment based on long-time environmental noise data. For environmental noise annoyance assessment based on individual noise measurements, it is better to use % HA, because it explains the higher percentage of results variability, compared to PHA.
- Night-time noise stands out as a problem since the expert public recognizes it as a significant factor responsible for the non-auditory effects of noise on human health and because the results of measurements of the Institute of Public Health of Vojvodina

confirm that the night-time noise is increased by 98% of measurements in the city traffic area.
- Monitoring of the implementation of preventive measures and evaluation of the activities undertaken to reduce the noise to which the human population is exposed is necessary.

Future research should be directed toward addressing the issue of providing adequate data collection infrastructure and determining the effect of action and implementation of proposed measures.

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