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LONG-TERM ROAD TRAFFIC NOISE MEASUREMENTS AT THE MAIN STREETS OF NIŠ CITY

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Abstract – *Environmental noise level monitoring in Serbia is performed in several cities and it is pursuant to the Law on Environmental Noise Protection and the accompanying regulations. Although these regulations are in accordance with the national standards, the methodology of noise monitoring varies in different cities. The issues which differ include the following: the number of measurement spots; the number of daily, weekly, and monthly measurement intervals, the duration of measurement intervals, measurement parameters and noise indicators used for noise evaluation. Different measurement procedures are the consequence of diverse city configurations, traffic structure, traffic flow, locations of noise-sensitive objects, as well as diverse contribution of noise sources. The road traffic noise level monitoring in the City of Nis has been organized from 1995 until today based on short-term measurements. The values of noise indicators are calculated based on these short-term measurements. The two newly purchased noise monitoring terminals by the Noise and Vibration Laboratory of the Faculty of Occupational Safety in Nis, enabled the long-term noise measurements. The procedure of permanent and semi-permanent road traffic noise measurements at eight locations in the City of Nis has been carried out since January 1, 2014. The results of long-term road noise measurements at the main streets of Niš city will be presented in this paper.*

1. INTRODUCTION

Noise pollution caused by road traffic represents a major problem in the environment of most urban areas. However, the problem of road traffic noise has not been approached properly so far, and not enough attention has been paid to it in spite of the fact that it has a great impact on the quality of life of the endangered population. Reasons for such an approach could be found in the definition of noise as a subjective experience of various external events, in its specific character, as well as in the difficulties connected to relating the causes with the effects it has on general health.

The latest data related to the environmental noise pollution [1], collected from the first round of strategic noise mapping of the European Union agglomerations, indicate that 54% of the population in urban areas (56,001,200 inhabitants) is exposed to L_{den} noise levels above 55dB, whereas 15% of the population (15,754,500 inhabitants) is exposed to L_{den} noise levels above 65dB. In addition to this, additional 33,437,244 inhabitants outside agglomerations live in areas where L_{den} noise levels exceed 55dB and 7,657,083 live in areas where L_{den} noise levels exceed 65dB. Out of the total of 89,438,444 inhabitants exposed to L_{den} noise levels above 55dB, almost 89 million are exposed to the traffic noise [1].

The conditions related to noise pollution in the city of Niš are in many ways similar to conditions in other urban environments. Collecting information on traffic characteristics and noise levels and updating it over a longer period has proven to be crucial to the evaluation and management of environmental noise. Furthermore, measurement and evaluation of traffic noise are important activities which may result in the development of efficient methods for noise control.

Data on traffic noise levels in the city of Nis have been systematically collected and analysed through the project of monitoring the noise level during a number of years starting from 1995 [2-5]. The road traffic noise level monitoring was based on short-term monitoring.

The obtained results give us an insight into the current condition of the noise level at specific locations, allowing us to compare them to previous measurement results and use this to evaluate tendencies related to possible changes in the future.

Two newly purchased noise monitoring terminals in Noise and Vibration Laboratory enable the long-term noise measurements.

The procedure of permanent and semi-permanent road traffic noise monitoring, starting from January 1, 2014 according to guidelines given in standards SRPS ISO 1996-1 [6] and SRPS ISO 1996-2 [7] and IMAGINE document [8] has been carried out eight locations.

The first results of one-year long-term measuremts were published in some papers [9-11]. Some od the results are publicaly available at web site http://www.znrfak.ni.ac.rs/BVLab-KMB/KMB-Home.html.

The results avialaibel until time of publication of this paper will be presented in the paper.

2. MEASUREMENT LOCATIONS FOR LONG-TERM MEASUREMENTS

The procedure of long-term measuremetas is realized as semi-permanent noise monitoring with different monitoring time. Semi-permanent monitoring, ranging from a three months to two years is more cost-effective monitoring than permanent noise monitoring that includes 24 hours a day, 365 days a year noise measurements using a permanently installed noise monitoring terminal at one location.

Brüel&Kjær's Environmental Noise Management System [9-11] was used for long-term noise monitoring. This system consists of Environmental Noise Management System Software, Type 7843, two Noise Monitoring Terminals (NMT), Type 3639B and one Weather Station, Type WXT520.

Both NMTs are equipped with GPRS router and GPS receiver. One of the terminals (marked as NMT-1) is equipped with weather station, which enable measurement of the following meteorological parameters: temperature, humidity, air pressure, wind velocity, wind direction and rainfall.

The procedure of long-term measurements is realized at eight measurements locations. There are the different methods for the selection measurement locations [12]. The choice of measurement locations was done in accordance with population and residential location, characteristics of land-uses and road functions and structure. The distribution of the measurements locations is given in Fig. 1.

The mark and basic information about measurement locations are given below.

Network of NMT locations is shown in Fig. 1

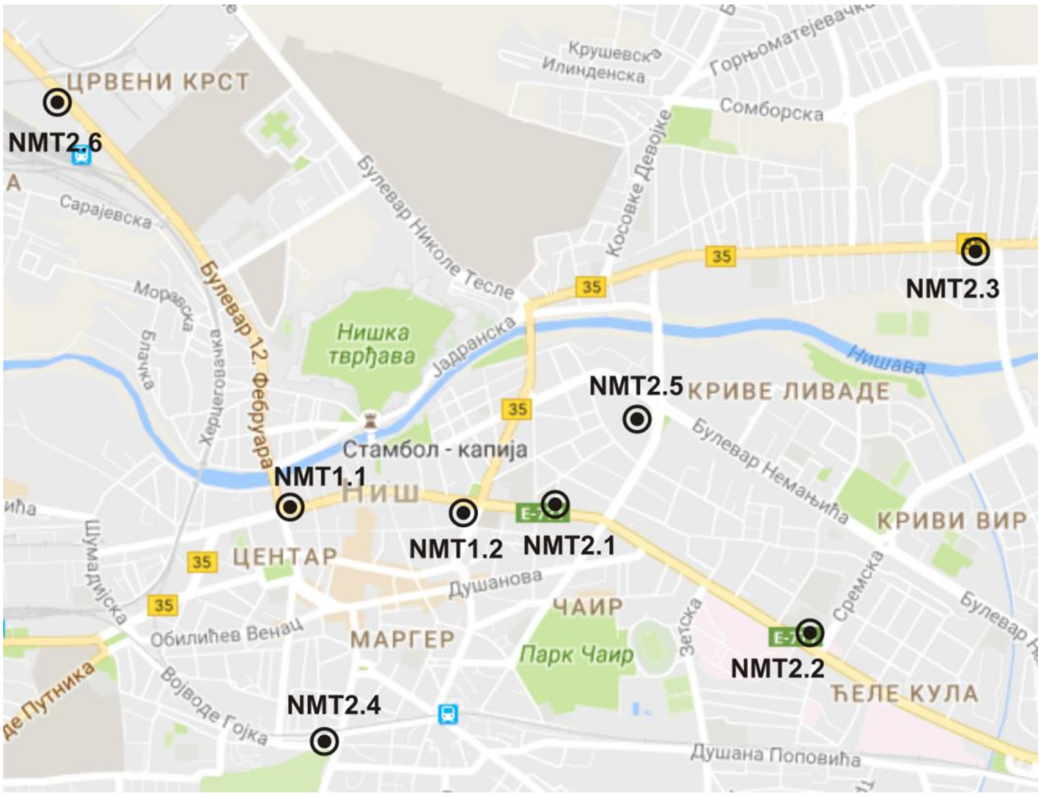

Fig. 1 *Network of NMT locations*

NMT1.1: Intersection of Kneginje Ljubice street and Generala Milojka Lešjanina street

Latitude: 43° 19’ 12.8”

Longitude: 21° 53’ 27.6”

Altitude: 195.3 m

Microphone height: 4 m

Mounting type: the lighting pole

Monitoring time: two years (01.01.2014 - 31.12.2015)

NMT1.2: Intersection of Kralja Stefana Prvovečanog street and Vožda Karađorđa street

Latitude: 43° 19’ 14”

Longitude: 21° 54’ 01”

Altitude: 197 m

Microphone height: 4 m

Mounting type: the lighting pole

Monitoring time: in progress (01.01.2016 -)

Plan of monitoring time: one year

NMT2.1: Primary school “Vožd Karađorđe” near Vožda Karađorđa street

Latitude: 43° 19’ 13”

Longitude: 21° 54’ 13.2”

Altitude: 196.8

Microphone height: 4 m

Mounting type: the lighting pole

Monitoring time: six months (01.01.2014 - 30.06.2014)

NMT2.2: Faculty of Medicine near Dr Zorana Đinđića street

Latitude: 43° 19’ 12”

Longitude: 21° 53’ 27”

Altitude: 197.1

Microphone height: 4 m

Mounting type: the separate pole

Monitoring time: nine months (01.07.2014 - 31.03.2015)

NMT2.3: Residential building near Knjaževačka street

Latitude: 43° 19’ 46”

Longitude: 21° 55’ 58”

Altitude: 212

Microphone height: 4 m

Mounting type: facade

Monitoring time: three months (01.04.2015 - 30.06.2015)

NMT2.4: Commercial building near railway Niš-Sofia-Niš

Latitude: 43° 18’ 46”

Longitude: 21° 53’ 36”

Altitude: 205

Microphone height: 4 m

Mounting type: facade

Monitoring time: six months (01.07.2015 -31.12.2015)

NMT2.5: Day nursery “Bamby” near Bulevar Nemanjića street

Latitude: 43° 19’ 26”

Longitude: 21° 54’ 31”

Altitude: 196

Microphone height: 4 m

Mounting type: the lighting pole

Monitoring time: six months (01.01.2016 -30.06.2016)

NMT2.6: Municipality building near 12. februara street

Latitude: 43° 20’ 2.7”

Longitude: 21° 52’ 51.9”

Altitude: 206

Microphone height: 4 m

Mounting type: the lighting pole

Monitoring time: in progress (01.07.2016 –)

Plan of monitoring time: six months

3. RESULTS OF ROAD TRAFFIC NOISE MONITORING

Monthly values of noise indicators for all locations as well as the results of statistical analysis (energetic mean value, standard deviation and maximum deviation of individual values from the energetic mean value) are shown in following tables.

The main values of noise indicators for all locations are shown in Fig. 2.

Fig. 1 *The values of* $L_{day}/L_{evening}/L_{night}/L_{den}$ *in dB*

Table 1 *The monthly noise indicators in dB for NMT-1.1*

	L_d	L_e	L_n	L_{den}	$L_{eq,total}$
January 2014	73.1	71.9	67.9	75.9	71.7
February 2014	73.1	71.9	67.7	75.8	71.7
March 2014	73.3	72.1	67.9	76.0	71.9
April 2014	73.4	72.4	68.3	76.3	72.0
May 2014	73.3	72.3	68.1	76.2	71.9
June 2014	73.0	72.0	68.1	76.0	71.7
July 2014	72.8	72.2	67.8	75.8	71.5
August 2014	72.7	71.9	68.2	76.0	71.5
September 2014	73.1	72.0	67.9	75.9	71.7
October 2014	73.2	72.1	68.0	76.0	71.9
November 2014	73.0	72.0	67.6	75.7	71.6
December 2014	73.3	72.4	68.2	76.2	72.0
mean value	**73.1**	**72.1**	**68.0**	**76.0**	**71.8**
σ	0.20	0.17	0.22	0.17	0.18
max. deviation	0.4	0.3	0.4	0.3	0.3

Table 2 *The monthly noise indicators in dB for NMT-1.1*

	L_d	L_e	L_n	L_{den}	$L_{eq,total}$
January 2015	72.8	71.4	68.5	76.0	71.5
February 2015	72.8	71.8	67.4	75.5	71.4
March 2015	73.2	72.1	67.8	75.9	71.8
April 2015	72.7	71.6	67.3	75.4	71.3
May 2015	72.5	71.4	67.3	75.3	71.2
June 2015	72.5	71.7	68.0	75.8	71.3
July 2015	72.1	71.3	67.5	75.3	70.9
August 2015	72.1	71.3	67.7	75.4	70.9
September 2015	72.6	71.5	67.4	75.4	71.3
October 2015	73.1	72.0	67.8	75.9	71.7
November 2015	72.9	71.6	67.7	75.7	71.5
December 2015	73.0	72.0	69.3	76.7	71.9
mean value	**72.7**	**71.6**	**67.8**	**75.7**	**71.4**
σ	0.35	0.28	0.58	0.41	0.31
max. deviation	0.6	0.4	1.5	1.0	0.5

Table 3 *The monthly noise indicators in dB for NMT-1.2*

	L_d	L_e	L_n	L_{den}	$L_{eq,total}$
January 2016	69.4	69.3	65.8	73.4	68.5
February 2016	69.2	68.5	64.8	72.6	68.1
March 2016	69.4	69.0	65.0	72.8	68.3
April 2016	69.0	68.7	64.7	72.5	67.9
May 2016	69.2	69.4	65.6	73.2	68.3
June 2016	69.0	69.1	64.9	72.7	68.0
July 2016	68.8	68.7	65.4	72.9	67.9
August 2016	68.8	69.1	67.4	74.2	68.5
September 2016	69.5	70.1	65.5	73.3	68.6
mean value	**69.1**	**69.1**	**65.5**	**73.1**	**68.2**
σ	0.26	0.48	0.82	0.53	0.27
max. deviation	0.4	1.0	1.9	1.1	0.4

Table 4 *The monthly noise indicators in dB for NMT-2.1*

	L_d	L_e	L_n	L_{den}	$L_{eq,total}$
January 2014	70.3	69.9	67.4	74.7	69.4
February 2014	70.2	69.7	66.7	74.1	69.2
March 2014	70.6	69.8	66.7	74.2	69.5
April 2014	70.5	70.2	67.2	74.6	69.6
May 2014	70.6	70.3	66.8	74.4	69.6
June 2014	70.1	69.7	66.6	74.0	69.1
mean value	**70.4**	**69.9**	**66.9**	**74.3**	**69.4**
σ	0.19	0.26	0.35	0.26	0.18
max. deviation	0.3	0.4	0.5	0.4	0.3

Table 5 *The monthly noise indicators in dB for NMT-2.2*

	L_d	L_e	L_n	L_{den}	$L_{eq,total}$
July 2014	63.5	63.0	57.6	66.1	62.2
August 2014	62.2	62.0	57.5	65.5	61.1
September 2014	63.1	62.5	57.9	66.0	61.8
October 2014	63.4	62.8	57.9	66.2	62.1
November 2014	63.3	62.8	57.9	66.2	62.1
December 2014	63.7	63.0	58.2	66.5	62.4
January 2015	62.8	61.7	57.4	65.5	61.4
February 2015	63.1	62.7	57.9	66.1	61.8
March 2015	63.6	63.0	58.3	66.5	62.3
mean value	**63.2**	**62.6**	**57.8**	**66.1**	**61.9**
σ	0.46	0.47	0.30	0.36	0.43
max. deviation	1.0	1.0	0.4	0.6	0.8

Table 6 *The monthly noise indicators in dB for NMT-2.3*

	L_d	L_e	L_n	L_{den}	$L_{eq,total}$
April 2015	62.6	61.9	57.2	65.4	61.2
May 2015	62.0	61.3	56.8	64.9	60.7
June 2015	62.1	61.5	56.9	65.0	60.8
mean value	**62.2**	**61.6**	**57.0**	**65.1**	**60.9**
σ	0.32	0.31	0.21	0.26	0.26
max. deviation	0.4	0.3	0.2	0.3	0.3

Table 7 *The monthly noise indicators in dB for NMT-2.4*

	L_d	L_e	L_n	L_{den}	$L_{eq,total}$
July 2015	62.9	62.2	60.4	67.4	62.1
August 2015	62.1	61.4	59.8	66.8	61.3
September 2015	63.0	61.8	58.8	66.4	61.8
October 2015	63.7	61.9	59.2	66.8	62.3
November 2015	63.6	61.2	59.8	67.0	62.3
December 2015	63.8	62.4	60.6	67.7	62.7
mean value	**63.2**	**61.8**	**59.8**	**67.0**	**62.1**
σ	0.65	0.46	0.69	0.47	0.48
max. deviation	1.1	0.6	1.0	0.7	0.8

Table 8 *The monthly noise indicators in dB for NMT-2.5*

	L_d	L_e	L_n	L_{den}	$L_{eq,total}$
January 2016	65.5	64.3	59.8	68.8	64.2
February 2016	65.5	64.8	59.3	68.2	64.4
March 2016	65.7	64.7	59.4	68.0	64.2
April 2016	65.0	64.5	59.4	67.6	63.6
May 2016	65.2	65.1	59.6	68.0	64.0
June 2016	64.6	64.9	59.4	67.8	63.5
mean value	**65.3**	**64.7**	**59.5**	**68.1**	**64.0**
σ	0.40	0.29	0.18	0.41	0.36
max. deviation	0.7	0.4	0.3	0.7	0.5

Table 9 *The monthly noise indicators in dB for NMT-2.6*

	L_d	L_e	L_n	L_{den}	$L_{eq,total}$
July 2016	67.9	67.5	63.9	71.5	66.9
August 2016	68.2	67.9	64.1	71.8	67.1
September 2016	68.7	69.6	64.0	72.3	67.8
mean value	**68.3**	**68.3**	**64.0**	**71.9**	**67.3**
σ	0.40	1.12	0.10	0.40	0.47
max. deviation	0.4	1.3	0.1	0.4	0.5

The monthly values of noise indicators for all locations are slightly different from the energetic mean values of noise indicators for observation interval except for the case of occasional occurrences such as New Year`s celebration (NMT1.1. – December 2015), celebration of Olympic champion in water polo (NMT1.2 – August 2016).

4. IN PLACE OF CONCLUSION – NEW APPROACH FOR ENVIRONMENTAL NOISE ASSESSMENT

It currently remains difficult for people to understand the environmental noise data due to various noise indicators that are expressed in decibel unit which is logarithmic in nature, and usually complicated to explain and relatively far-removed from perception of people. Also, the noise indicators very often are expressed in dB(A), which further complicates the understanding of noise indicators values.

Two French organizations specialized for management and organization of urban noise observatories in France, have worked on a proposal for a new index closer to the perception of the people [13, 14]. They suggested a new environmental noise index called Harmonica (HARMOnised Noise Information for Citizens and Authorities) index. The Harmonica index is based on measurement data obtained by noise monitoring and take into account both the overall environmental noise load and noise peaks from sudden noise events.

The Harmonica index is calculated based on one-hour time sample of A-weighted, equivalent continuous sound level sampled with 1 second interval, and it takes into account the two major components that affect the sound environment.

The Harmonica index is an adimensional index based on a scale of 0 to 10. The Harmonica index is graphically represented as a triangle (BGN component) on top of a rectangle (EVT component). Three colors (green, orange and red) are used for color representation of the Harmonica index. The color scale is shown in Table 10.

Table 10. *The color scale for Harmonica index*

Color	Day (from 6 am to 10 pm)	Night (from 10 pm to 6 am)	Harmonica index score
green	between 0 and 4	between 0 and 3	Quiet
orange	between 4 and 8	between 3 and 7	Noisy
red	over 8	over 7	Very noisy

The detailed information about Harmonica index, calculation procedure and the results of environmental noise assessment by Harmonica index in the city of Nis are given in papers [15, 16].

Two example of Harmonica index calculation are given in Fig. 3 and Fig.4.

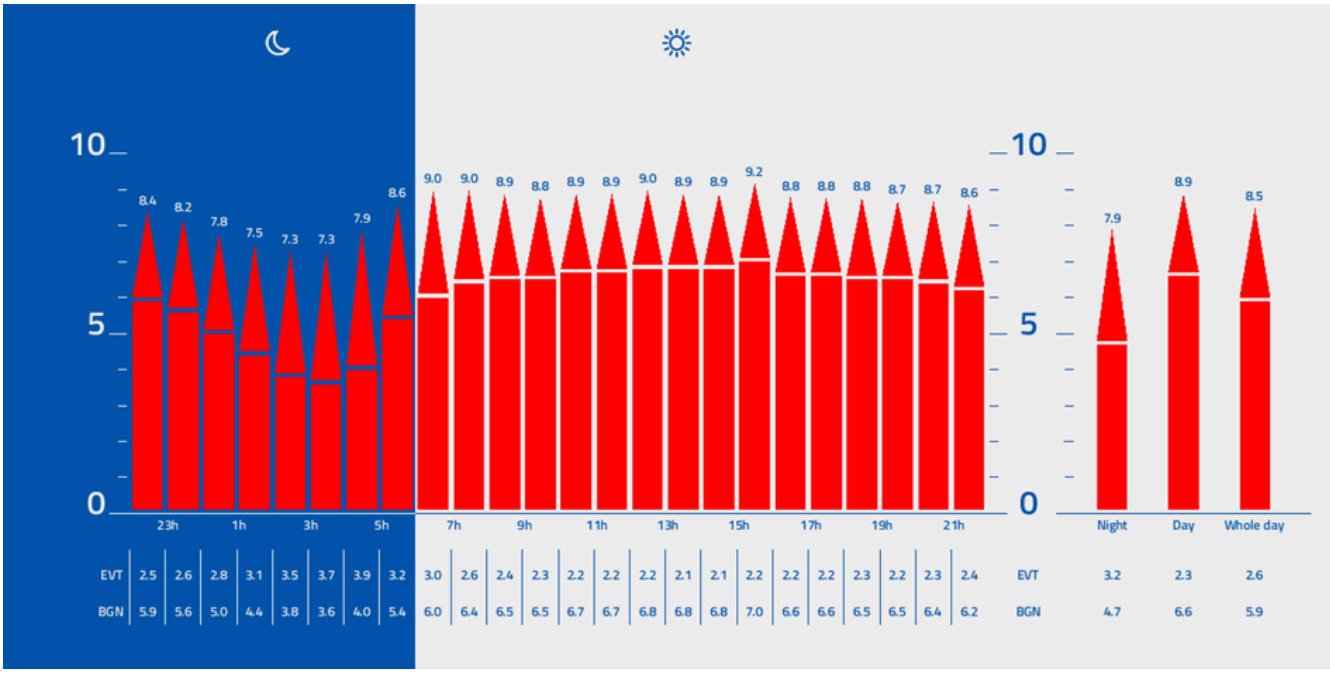

Fig. 3. *The averaged hourly values of Harmonica indices for NMT-1.1 (April 20, 2015- April 26, 2015)*

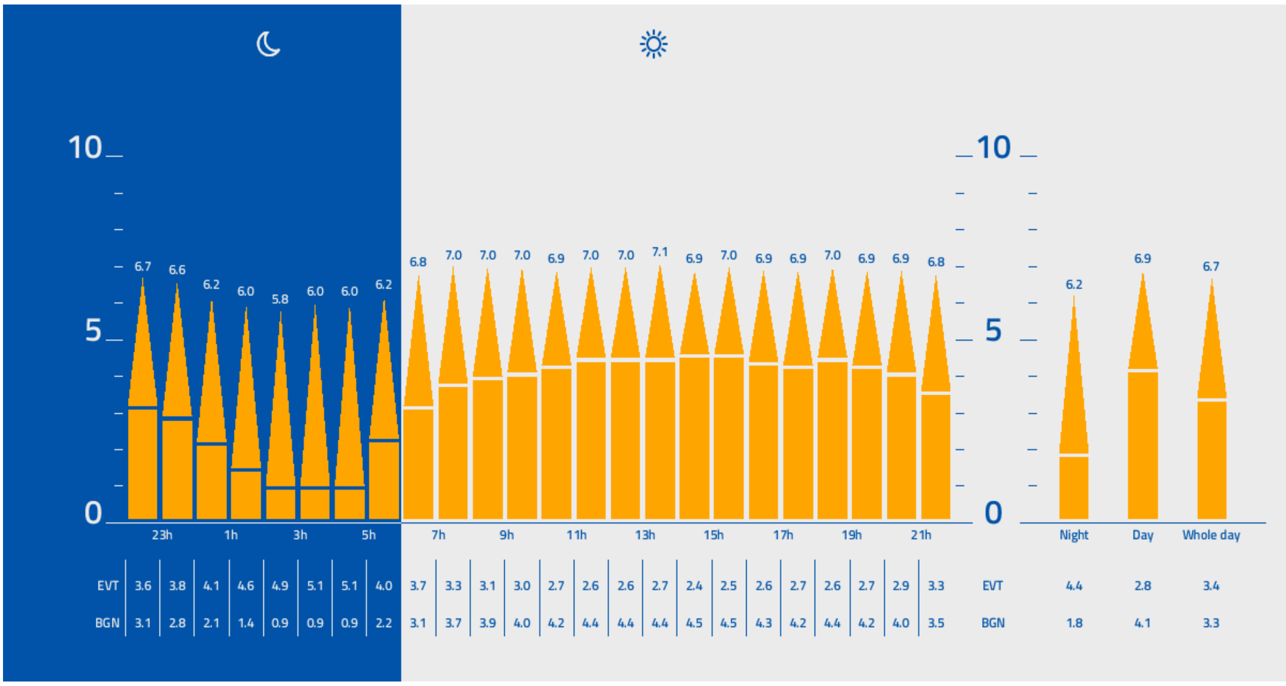

Fig. 4. *The averaged hourly values of Harmonica indices for NMT-2.3 (April 20, 2015- April 26, 2015)*

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11th Yugoslav Conference & 1st International Conference	Belgrade	1988
12th Yugoslav Conference	Belgrade	1989
13th Yugoslav Conference	Niš	1991
14th Yugoslav Conference & 2nd International Conference	Niš	1993
15th Yugoslav Conference & 3rd International Conference	Niš	1995
16th Yugoslav Conference with international participation	Niš	1998
17th Yugoslav Conference with international participation	Niš	2000
18th Yugoslav Conference with international participation	Niš	2002
19th Conference with international participation	Niš	2004
20th Conference with international participation	Tara	2006
21st Conference with international participation	Tara	2008
22nd Conference with international participation	Niš	2010
23rd Conference and 4th International Conference	Niš	2012
24th International Conference	Niš	2014
25th International Conference	Tara	2016

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