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PERMANENT AND SEMI-PERMANENT NOISE MONITORING - FIRST RESULTS IN THE CITY OF NIS

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Abstract – *Environmental Noise Directive and the Serbian regulations introduce the new noise indicators for environmental noise assessment. For the purposes of strategic noise mapping and assessment of noise harmfull effects it is necessary to determine the annual value of these indicators. Two measurement principles were developed for determination of noise indicators by long-term or short-term measurements. The long-term measurements can be realized as permanent noise monitoring or semi-permanent noise monitoring. Permanent monitoring can indicate environmental noise trends and help produce noise maps. Semi-permanent monitoring, typically ranging from a few days up to several weeks or months, is also used for cost-effective monitoring of environmental noise trends, limit compliance, public awareness, the improved knowledge of dose-response relationships and the calibration of noise maps. The procedure of permanent and semi-permanent environmental noise measurements at three locations in the city of Niš has been carried out starting from January 1, 2014. The first results of these measurements will be presented in this paper.*

1. INTRODUCTION

Regarding the state of the used noise indicators in European countries, there was a need to harmonize ones. By adopting the Directive on the Assessment and Management of Environmental Noise, 2002/49/EC [1], the basic principles of a harmonized European noise policy were defined. One of the key elements of the Environmental Noise Directive is the assessment of environmental noise by common noise indicators and common assessment methods.

The Environmental Noise Directive has been transposed in Serbian legislation by the adoptaion of the Law on Environmental Noise Protection in 2009 (revised in 2010) [2] and several national sub-laws adopted in 2010. Regulation on noise indicators, limit values, assessment methods, noise annoyance, noise effects, impact on health, collecting data for noise assessment [3] introduce the noise indicators defined in the Environmental Noise Directive.

Directive [1] and Serbian legislation [2,3] require the use the common and supplement noise indicators. The common noise indicators are:

- the day-evening-night noise indicator, L_{den}[dB(A)] - indicator describing the overall annoyance caused by noise within 24 hours, i.e. for the day-evening-night;
- the daily noise indicator, L_d [dB(A)] - indicator describing the annoyance caused by noise within the day (from 6 a.m. to 6 p.m.);
- the evening noise indicator, L_e [dB(A)] - indicator describing the annoyance caused by noise during the evening (from 6 p.m. to 10 p.m.);
- the night-time noise indicator, L_n [dB(A)] - indicator describing the sleep distrubance caused by noise at night (from 10 p.m. to 6 a.m.).

The day-evening-night noise indicator is defined by the following formula:

$$L_{den} = 10\,\mathbf{log}\frac{1}{24}\left(12\cdot 10^{0.1\cdot L_d} + 4\cdot 10^{0.1\cdot(L_e+5)} + 4\cdot 10^{0.1\cdot(L_n+10)}\right) \quad (1)$$

where:

L_d - the A-weighted long-term average sound level determined over all the day periods of a year,

L_e - the A-weighted long-term average sound level determined over all the evening periods of a year,

L_n - the A-weighted long-term average sound level determined over all the night periods of a year.

A year is a relevant year as regards the emission of sound and an average year as regards the meteorological circumstances [1].

The A-weighted long-term average sound levels for different day periods of a year are defined by the following formula:

$$L_{d(e,n)} = 10\log\left[\frac{1}{N}\sum_{i=1}^{N}10^{0.1\cdot L_{d(e,n),i}}\right] \quad (2)$$

where N is the number of days in a year, N = 365.

The values of noise indicators for i-th day in year are determined based on the continuous measurement of the equivalent noise level in day periods, or by sampling techniques during day periods.

2. NOISE MONITORING STRATEGIES

IMAGINE document [4] describes how to determine L_{den} and L_n by direct measurement or by extrapolation of measurement results by means of calculation. The measurement method is intended to be used outdoors as a basis for assessing environmental noise and verifying the quality of predictions. Also, the revision of ISO 1996-2 standard that will provide the guidelines for noise indicators determination is in progress.

Two measurement principles were developed for determination of noise indicators. First, the long-term measurements involve measurements during a time long enough to include all variations in operating and meteorological conditions of noise source. Second, the short-term measurements involve measurements under specified operating and meteorological conditions of noise source and the use of relevant prediction method in order to determine the noise indicators value.

For long-term measurements, measurement time interval shall be some significant fraction of a year (e.g. 3 months, 6 months, 1 year), while for the short-term measurements, the minimal time interval shall be 10 minutes but 30 minute measurement is recommended in order to average weather induced variations.

The results of long-term measurements are more accurate and can be used with fewer corrections than those of short-term measurements.

The long-term measurements can be realized using two measurement strategies:

- permanent noise monitoring or
- semi-permanent noise monitoring.

The permanent noise monitoring includes 24 hour a day, 365 days a year, noise measurements using a permanently installed noise monitoring terminal (NMT). The permanent monitoring can indicate environmental noise trends and help produce noise maps.

The semi-permanent monitoring, typically ranging from a few days up to several weeks or months, is also used for cost-effective monitoring of environmental noise trends, limit compliance, public awareness, the improved knowledge of dose-response relationships and calibration of noise maps. The quickly and easily moved noise monitoring terminal are used for the semi-permanent monitoring.

The optimal duration of semi-permanent monitoring cannot be easily determined. Noise source operating conditions, e.g. traffic composition and vehicle flow conditions, shall be as representative as possible to minimize later corrections. If propagation conditions or emission conditions vary strongly between the different seasons of the year, e.g. because of winter tires and snow cover, it might be necessary to perform measurement during several different seasons in order to achieve a low measurement uncertainty.

3. SHORT REVIEW OF NOISE MONITORING IN THE SERBIA

Environmental noise level monitoring in Serbia is performed in several cities and it is pursuant to the Law of environmental noise protection and the accompanying regulations. Although these regulations are in accordance with the national standards [5,6], the methodology of noise monitoring varies in different cities. The issues which differ include as follows: 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 [7]. Different measurement procedures result from different city configurations, the traffic structure, the traffic flow, the arrangement of noise-sensitive objects, and different shares of noise sources.

The current practice of noise monitoring and assessment in Serbia usually implies short-time measurements with 15-min time interval together with recording general traffic and site information [7]. The measurement period is extended to 1 h in some cases. Continuous twenty-four hours noise level measurements have lately taken place in some cities (for example: Novi Sad, Belgrade, and Pancevo), while the long-term noise measurements by semi-permanent noise monitoring have been carried out lately only in Novi Sad [8].

The environmental noise level monitoring in the city of Niš has been organized on a monthly basis, for the reference time intervals since 1995 until today. The daytime measurement interval is divided into 3 or 5 periods, whereas the night time measurement interval is divided into 2 periods. Within one cycle/month interval there is one 15 minute measurement at each determined measurement spot and for each mentioned period. The values of noise indicators are calculated based on these short-term measurements. The results of calculation are shown in [9].

The two newly purchased noise monitoring terminals by 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 environmental noise measurements at three locations in the city of Nis is being carried out starting from January 1, 2014

The research has been conducted with the aim of determination of the optimal duration of semi-permanent monitoring that would enables the cost-effective monitoring of environmental noise and the determination of the noise indicators at multiple locations with only two noise monitoring stations.

4. METHODOLOGY OF PERMANENT AND SEMI-PERMANENT NOISE MONITORING IN THE CITY OF NIS

Brüel&Kjær's Environmental Noise Management System (Fig. 1) used to permanent noise monitoring consists of:

- Environmental Noise Management System Software Type 7843
- Two Noise Monitoring Terminals Type 3639B

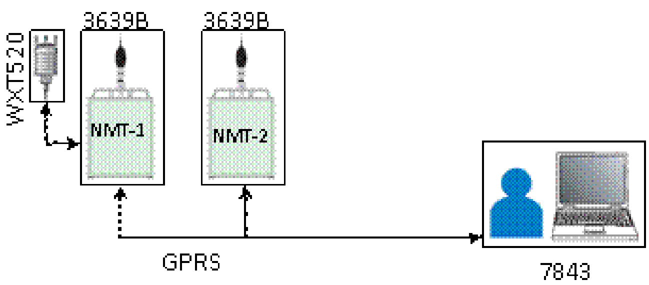

Fig. 1 *Environmental Noise Management System*

The Environmental Noise Management System (ENMS) is built around a server and a set of clients with a professional Microsoft® SQL Server® database as the central server component [10]. The ENMS server provides the basic data storage and business logic for accessing objects in the ENMS database. The server receives data from two noise monitoring terminals (NMT) that provides the server with noise and weather data and stores data and measurement setups as templates.

Environmental Noise Management System Software Type 7843, the central part of the ENM makes it a powerful noise data management tool. It offers real-time communication with NMTs ensuring continuous data storage in both the NMTs and the system's central database. The software ensures data retrieval, analysis, reporting and export of noise, weather, and geographic data through its configurable user interface with built-in GIS functionality.

Noise Monitoring Terminal Type 3639-B is a self-calibrating NMT optimized for remote, unattended, environmental noise measurements [11]. It can measure, record, process, store, and transmit noise information as part of a noise monitoring system. The NMT consists of a weatherproof cabinet containing a noise level analyzer and a battery, a GPRS router, GPS receiver and an outdoor microphone, all of which can be mounted on a mast, pole, tripod or wall. Noise monitoring and analysis is performed by the included analyzer Type 2250 protected inside the cabinet which measures data coming from the outdoor microphone and logs it onto its on-board memory, including broadband and 1/3-octave L_{Aeq} or SPL, continuously at half- or one second intervals. The NMT can also identify, record and analyze noise events. Analyses produced include: hourly reports, short reports (from 1 to 30 minutes), calibration check reports, noise events and instrument health reports.

The procedure of permanent environmental noise monitoring, starting from January 1, 2014 according to guidelines given in standards SRPS ISO 1996-1 [5] and SRPS ISO 1996-2 [6] and IMAGINE document [4] has been carried out at location near the intersection of two roads (marked as NMT-1). The procedure of semi-permanent monitoring starting from July 1, 2014 has been carried out at location near a faculty (marked as NMT-2.2). Location of noise monitoring terminals is shown on Fig. 2 and the coordinates are shown in Table 1.

Table 1 *The coordinates of noise monitoring terminals*

	NMT-1	NMT-2.1	NMT-2.2
Latitude	43° 19' 12.8"	43° 19' 13"	43° 19' 12"
Longitude	21° 53' 27.6"	21° 54' 13.2"	21° 53' 27"
Altitude	195.3 m	196.8 m	197.1 m
Microphone height	4 m	4 m	4 m

The NMTs were mounted on the lighting pole at location NMT-1 (Fig. 3) and NMT-2.1, while the NMT was mounted on the separate pole at location NMT-2.2 (Fig. 4).

Fig. 2 *Location of noise monitoring terminals on GIS plan of the city of Nis*

Fig. 3 *NMT mounted on the lighting pole (location NMT-1: Intersection of two roads)*

Fig. 4 *NMT mounted on the separate pole (location NMT-2.2: Faculty of Medicine)*

The NMTs were connected to constant supply during all day at location NMT-1 and NMT-2.2, while the NMT was connected to constant external AC power supply during night at location NMT-2.1. If long-term monitoring is required, constant AC power from an external mains source is the most reliable and convenient than occasional external AC power.

Both NMTs are equipped with GPRS router and GPS receiver. One of the terminals (marked as NMT-1) is equipped with Weather Station Type WXT520 manufactured by Vaisala, which enable measurement of the following meteorological parameters: temperature, humidity, air pressure, wind velocity, wind direction and rainfall.

The measurement settings of NMTs is shown in Fig. 5. The weather paramenters are valid only for NMT-1. The time for performing charge injection calibration (CIC) was defined for checking system. CIC has been perfomed one time every 24 hours.

The system generates four default period reports based on the noise data: hour, day, month and year reports. It can be defined twelve additional periodical reports. Three additional reports were defined for purpose of this research: working day, weekend and week.

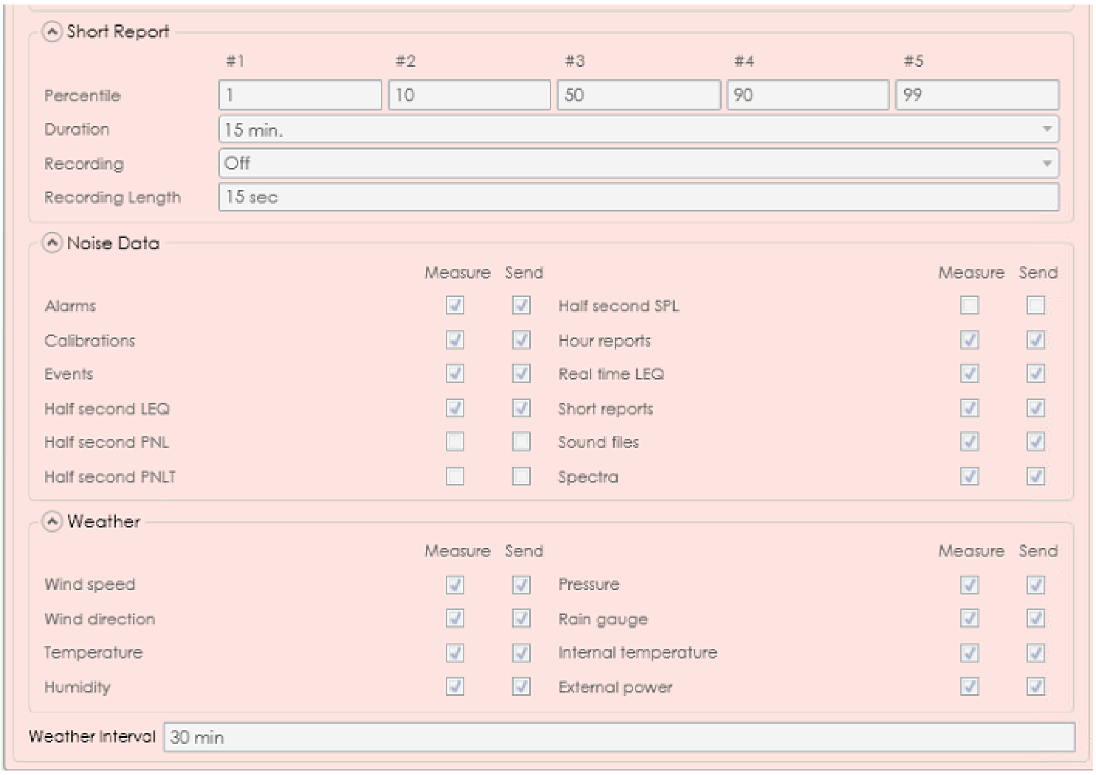

Fig. 5 *Parameter settings of NMTs*

5. RESULTS OF NOISE MONITORING

The monthly values of the noise indicators for NMT-1, NMT-2.1 and NMT2.2 are shown in Table 2, Table 3 and Table 4, respectively, as well as the results of statistical analysis (mean value and standard deviation).

Table 2 *The monthly noise indicators in dB(A) for NMT-1*

	L_d	L_e	L_n	L_{den}	$L_{eq,total}$
January	73.1	71.9	67.9	75.9	71.7
February	73.1	71.9	67.7	75.8	71.7
March	73.3	72.1	67.9	76.0	71.9
April	73.4	72.4	68.3	76.3	72.0
May	73.3	72.3	68.1	76.2	71.9
June	73.0	72.0	68.1	76.0	71.7
July	72.8	72.2	67.8	75.8	71.5
August	72.7	71.9	68.2	76.0	71.5
September	73.1	72.0	67.9	75.9	71.7
mean value	**73.1**	**72.1**	**68.0**	**76.0**	**71.7**
σ	**0.21**	**0.16**	**0.19**	**0.15**	**0.17**

Table 3 *The monthly noise indicators in dB(A) for NMT-2.1*

	L_d	L_e	L_n	L_{den}	$L_{eq,total}$
January	70.3	69.9	67.4	74.7	69.4
February	70.2	69.7	66.7	74.1	69.2
March	70.6	69.8	66.7	74.2	69.5
April	70.5	70.2	67.2	74.6	69.6
May	70.6	70.3	66.8	74.4	69.6
June	70.1	69.7	66.6	74.0	69.1
mean value	**70.4**	**69.9**	**66.9**	**74.3**	**69.4**
σ	**0.17**	**0.24**	**0.32**	**0.24**	**0.16**

Table 4 *The monthly noise indicators in dB(A) for NMT-2.2*

	L_d	L_e	L_n	L_{den}	$L_{eq,total}$
July	63.5	63.0	57.6	66.1	62.2
August	62.2	62.0	57.5	65.5	61.1
September	63.1	62.5	57.9	66.0	61.8
mean value	**62.9**	**62.5**	**57.7**	**65.9**	**61.7**
σ	**0.54**	**0.41**	**0.17**	**0.26**	**0.45**

The daily values of the noise indicators for NMT-1, NMT-2.1 and NMT-2.2 are shown in Fig. 6, Fig. 7 and Fig. 8, respectively. The values of L_e noise indicator are omitted due to clarity of figure. Otherwise, the values of L_d noise indicator and L_e noise indicator are mainly very similar. The results of statistical analysis (mean value, standard deviation, maximum and minimum value) of daily values for NMT-1, NMT-2.2 and NMT-2.1 are shown in Table 5, Table 6 and Table 7, respectively. The results of statistical analysis of all daily values are shown in column 1, while the results of statistical analysis of daily values excluding weekend values are shown in column 2. The results of statistical analysis of daily values excluding value for January, 1 are marked with "*". The value of L_{den} noise indicator for January, 1 was much higher than other values due to the fireworks and the New Year celebration.

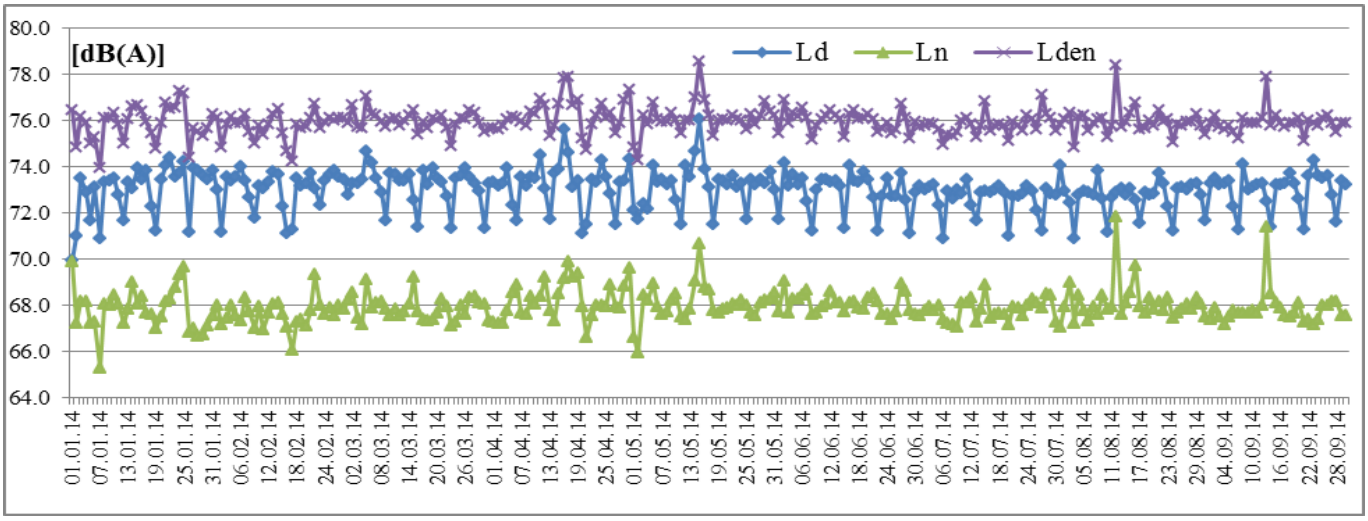

Fig. 6 *The daily values of noise indicators for NMT-1 for January-September 2014*

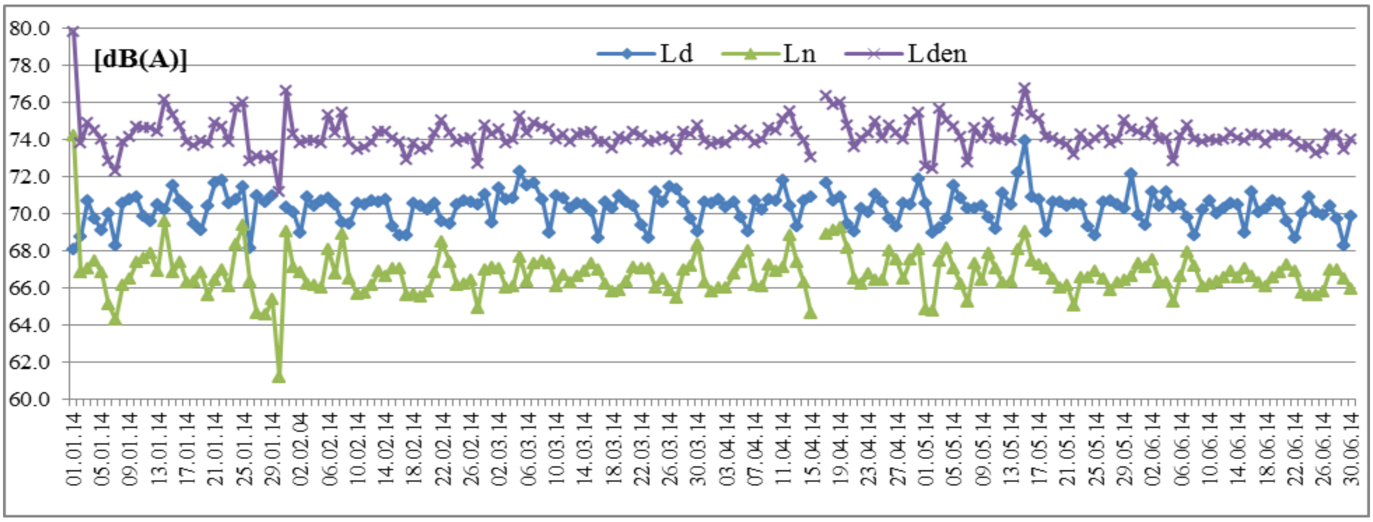

Fig. 7 *The daily values of noise indicators for NMT-2.1 for January-June 2014*

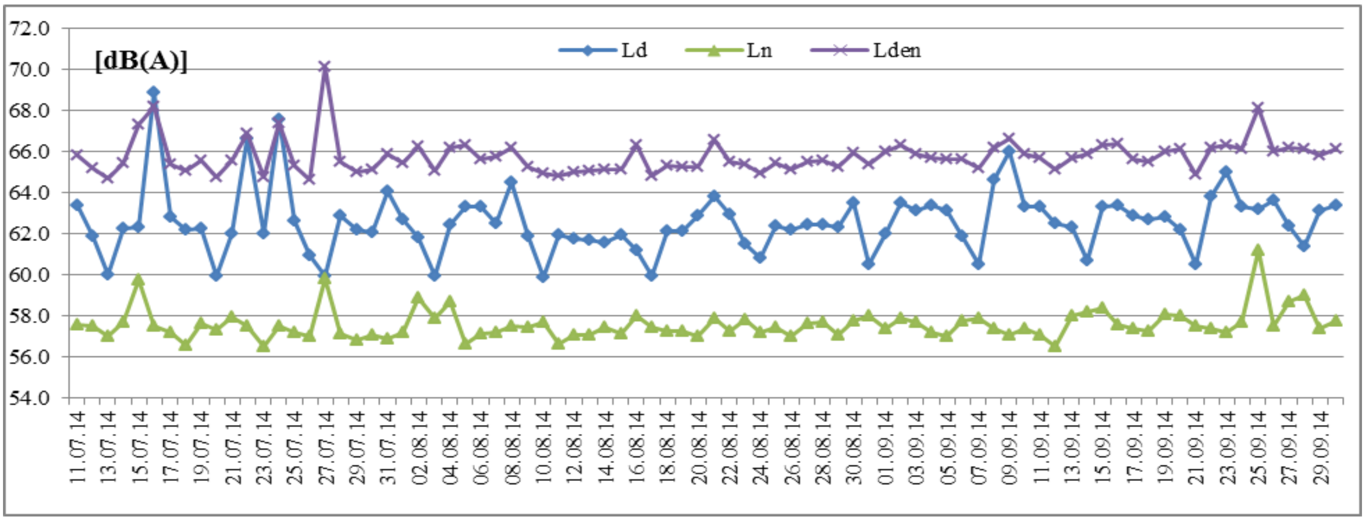

Fig. 8 *The daily values of noise indicators for NMT-2.2 for July-September 2014*

Table 5 *Statistical parameters of daily L_{den}, in dB(A), for NMT-1*

month	mean value		σ		max value		min value	
	1	2	1	2	1	2	1	2
I	75.9	76.0	0.77	0.69	77.3	77.3	74.0	74.0
II	75.8	75.9	0.54	0.45	76.7	76.5	74.2	74.2
III	76.0	76.1	0.39	0.31	77.0	77.0	74.9	75.7
IV	76.2	76.3	0.71	0.74	77.9	77.9	74.7	74.7
V	76.1	76.2	0.70	0.78	78.5	78.5	74.3	74.3
VI	76.0	76.2	0.43	0.33	76.9	76.9	75.2	75.5
VII	75.8	75.8	0.43	0.32	77.1	76.8	74.9	72.3
VIII	76.0	76.1	0.59	0.55	78.4	78.4	74.8	75.6
IX	75.9	75.9	0.45	0.16	77.9	76.2	75.1	75.6
I-IX	**76.0**	**76.1**	**0.59**	**0.55**	**78.5**	**78.5**	**74.0**	**74.0**

Table 6 *Statistical parameters of daily L_{den}, in dB(A), for NMT-2.2*

month	mean value		σ		max value		min value	
	1	2	1	2	1	2	1	2
VII	65.9	65.9	1.33	0.99	70.1	68.2	64.6	64.8
VIII	65.5	65.5	0.47	0.45	66.5	66.5	64.8	64.8
IX	66.0	66.1	0.55	0.56	68.1	68.1	63.9	65.1
VII-IX	**65.8**	**65.8**	**0.84**	**0.71**	**70.1**	**68.2**	**64.6**	**64.8**

Table 7 *Statistical parameters of daily L_{den}, in dB(A), for NMT-2.1*

month	mean value		σ		max value		min value	
	1	2	1	2	1	2	1	2
I	74.3	74.5	1.51	1.56	79.8	79.8	71.2	72.3
I*	74.2	74.3	1.15	1.08	76.6	76.6	71.2	72.3
II	74.0	73.9	0.60	0.59	75.4	75.3	72.7	72.7
III	74.2	74.1	0.37	0.39	75.2	75.2	73.5	73.5
IV	74.5	74.4	0.76	0.79	76.3	76.3	73.0	73.0
V	74.3	74.2	0.90	0.97	76.8	76.8	72.4	72.4
VI	74.0	74.0	0.41	0.42	74.9	74.9	72.8	72.8
I-VI	**74.2**	**74.2**	**0.87**	**0.95**	**79.8**	**79.8**	**71.2**	**71.2**
I-VI*	**74.2**	**74.1**	**0.77**	**0.81**	**76.8**	**76.8**	**71.2**	**71.2**

In addition to monthly and daily values of the noise indicators, the periodical values of the noise indicators for workdays, weekends and weeks were determined, i.e. five-day, two-day and seven-day values, respectively. The results of these noise indicators are shown in Fig. 9 and Fig. 10, for NMT-1 and NMT-2.1, respectively.

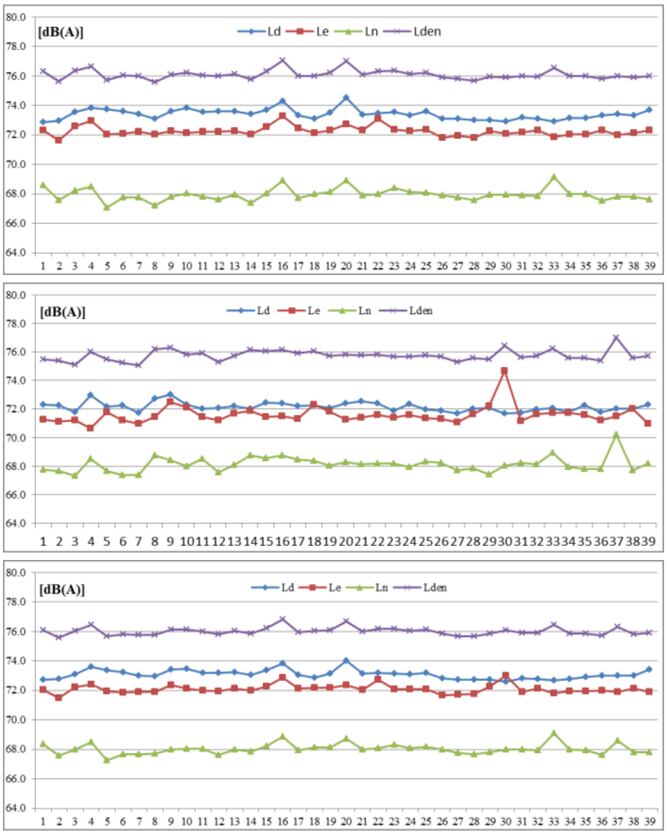

Fig. 9 *The periodical values of noise indicators for NMT-1 for January-Septembeer 2014 (upper graph – workday values, middle graph – weekend values, lower graph – week values)*

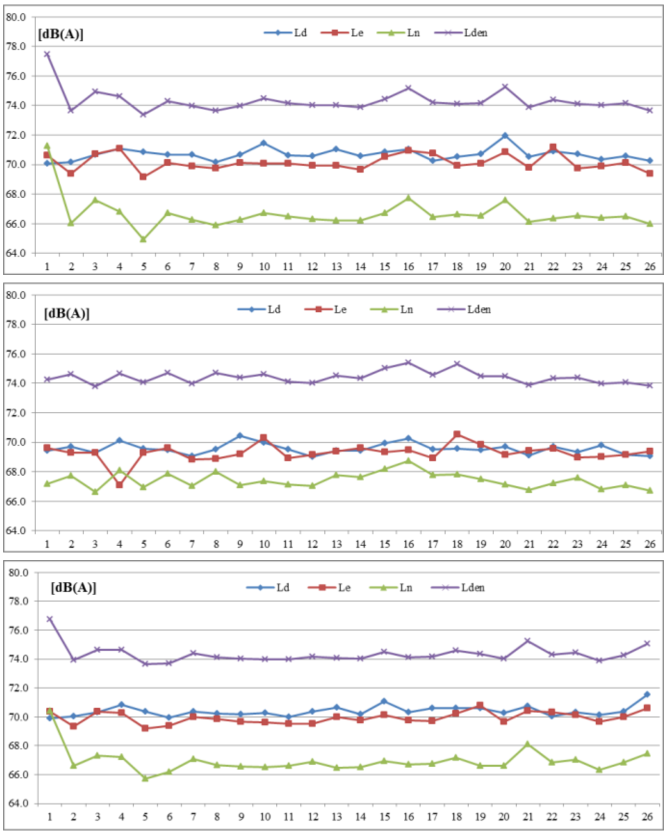

Fig. 10 *The periodical values of noise indicators for NMT-2.1 for January-June 2014 (upper graph – workday values, middle graph – weekend values, lower graph – week values*

The statistical parameters (mean value, standard deviation, maximum and minimum value) as the results of statistical analysis of the noise indicators for different monitoring periods (day, weekend, workday, week, month) were compared and the results of comparison are shown in Table 8 and Table 9, for NMT-1 and NMT-2.1, respectively.

Table 8 *Comparison of statistical parameters of noise indicators for different monitoring periods, in dB(A), for NMT-1*

		L_d	L_e	L_n	L_{den}	$L_{eq,total}$
month	mean value	73.1	72.1	68.0	76.0	71.7
	σ	0.21	0.16	0.19	0.15	0.17
	max value	73.4	72.4	68.3	76.3	72.0
	min value	72.7	71.9	67.7	75.8	71.5
day	mean value	73.0	72.0	68.0	76.0	71.7
	σ	0.88	0.75	0.71	0.59	0.70
	max value	76.0	76.7	71.8	78.5	74.4
	min value	70.0	69.5	65.3	74.0	69.8
week	mean value	73.1	72.1	68.0	76.0	71.8
	σ	0.31	0.29	0.36	0.27	0.26
	max value	74.0	73.0	69.1	76.8	72.5
	min value	72.6	71.5	67.2	75.6	71.4
work day	mean value	73.4	72.2	67.9	76.1	72.0
	σ	0.36	0.33	0.42	0.32	0.31
	max value	74.5	73.3	69.1	77.0	73.0
	min value	72.9	71.6	67.1	75.6	71.5
weekend	mean value	72.2	71.6	68.1	75.8	71.1
	σ	0.31	0.63	0.53	0.37	0.27
	max value	73.0	74.7	70.2	77.0	71.9
	min value	71.7	70.6	67.3	75.1	70.6

Table 9 *Comparison of statistical parameters of noise indicators for different monitoring periods, in dB(A), for NMT-2.1*

		L_d	L_e	L_n	L_{den}	$L_{eq,total}$
month	mean value	70.4	69.9	66.9	74.3	69.4
	σ	0.17	0.24	0.32	0.24	0.16
	max value	70.6	70.3	67.4	74.7	69.6
	min value	70.1	69.7	66.6	74.0	69.1
day	mean value	70.3	69.8	66.7	74.2	69.3
	σ	0.86	0.98	1.18	0.87	0.91
	max value	73.9	73.5	74.2	79.8	72.5
	min value	68.1	65.1	61.2	71.2	61.2
week	mean value	70.4	69.9	66.9	74.4	69.4
	σ	0.35	0.85	0.85	0.62	0.36
	max value	71.5	70.8	70.4	76.8	70.3
	min value	69.9	69.2	65.7	73.6	68.9
work day	mean value	70.7	70.1	66.7	74.3	69.6
	σ	0.39	0.53	1.07	0.76	0.42
	max value	71.9	71.2	71.3	77.5	70.7
	min value	70.1	69.2	64.9	73.4	69.0
weekend	mean value	69.6	69.3	67.4	74.4	68.9
	σ	0.36	0.59	0.51	0.41	0.30
	max value	70.5	70.5	68.7	75.4	69.7
	min value	69.0	67.1	66.6	73.8	68.5

CONCLUSION

Brüel&Kjær's Environmental Noise Management System described in this paper can be successfully used for long-term noise measurements. The results obtained by permanent and semi-permanent noise monitoring are very accurate and repeatable. The semi-permanent monitoring enables the cost-effective monitoring of environmental noise and the determination of the noise indicators at multiple locations with only few noise monitoring stations.

Based on the results of permanent and semi-permanent noise monitoring and the noise indicator determination by long-term measurements which are shown in this paper, the following conclusions can be derived:

- the monthly values of noise indicators for all three locations are slightly different from mean values of noise indicators for observation interval; the standard deviation for NMT-1 ranges from 0.15 dB(A) to 0.21 dB(A), for NMT-2.1 from 0.17 to 0.32 and for NMT-2.2 from 0.17 dB(A) to 0.54 dB(A);
- 95% of daily values of noise indicators are in the acceptable range of values; the value of daily and evening noise indicator are very similar;
- shorter monitoring periods (work days or week) give the very similar values to the monthly values; the mean values of week values and monthly values are almost identical, while the standard deviations of week values have acceptable value; the mean values of work day values and monthly values are very similar;

Generally, it can be concluded that the noise monitoring with duration of one month gives very accurate and repeatable values. Also, the noise monitoring with duration of one week or only work days gives very usable values but this conclusion should be confirmed for more locations, especially where the traffic conditions and the traffic noise are more variable.

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