JEE Journal of Ecological Engineering
Volume 19, Issue 4, July 2018, pages 159–166
https://doi.org/10.12911/22998993/89920

Received: 2018.04.12
Accepted: 2018.05.25
Published: 2018.07.01

Monitoring of Road Noise in the Urban Environment of Lublin

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ABSTRACT

In this article we presented the issues concerning the measurement of road noise, measurement results, and the discussion pertaining to the methods of limiting the excessive noise in the city of Lublin. Mobile systems, equipped with software which enables editing the measurement data, analysis and presentation of the data in the form of an acoustic map, are used to measure the noise level. Exemplary streets of the city are shown, where the road noise level has been significantly exceeded, and the effects of acoustic screens installation is presented. Moreover, the preventive and educational actions which are carried out in Lublin, meant to popularise alternative methods of transport, are discussed. It was concluded that an effective reduction of the traffic noise in the city can be achieved already at the stage of designing housing estates, along with the planning of access roads and noise barriers.

Keywords: road noise, means of transport, urban environment

INTRODUCTION

The noise originating from traffic is a factor which has a negative impact on the human health and on the natural environment. The noise levels on roads are most often between 55 dB and 65 dB. It was found that a prolonged exposure to the noise of such intensity is detrimental to the human health and results in stress reactions [Okokon et al. 2015]. The studies on road noise carried out in Stockholm have shown its influence on increasingly greater sleeping problems of its citizens. Sleeping disorders were much more often found in the persons living in the apartments with windows facing the street, as opposed to the persons whose bedroom windows were facing the "calm" side [Bluhm et al. 2004]. Apart from insomnia, the effects of long-term exposure to noise among people are: irritation, decreased efficiency, aggressive behaviour and an increased risk of a heart attack [Moudon 2009]. It was also concluded that people do not grow accustomed to the constant noise which can cause such ailments as asthma, headaches, depression and increased blood pressure [Ouis 2001].

The noise coming from the means of transport has been a major problem since the 1980s – more than a half of the respondents living in American cities had problems with the excessive noise, while 80% of them all thought that its main source is traffic or, in a broader sense, transport (road vehicles, rail vehicles, planes, water vehicles) [Brown and Lee 1987]. In Beijing, the main roads are congested with traffic during the day, and the noise level along these roads exceeds the appropriate environment protection standards by 5 dB. The unbalanced development of the infrastructure caused the diversification of traffic in this city. In the northern part, the traffic intensity is greater and the road noise level is higher than in the southern part of Beijing [Bengang Li et al. 2002]. The results of the tests concerning the exposure to noise of the citizens of Tainana (Taiwan) showed that more than 90% of the population is exposed to onerous acoustic conditions. In particular, the level of noise in commercial areas on summer evenings was 23 dB higher than the permitted level [Tsai et al. 2009]. Similar results of road traffic noise exposure can be found in Karachi (Pakistan). It was concluded that noise level in the morning and in the evening was higher due to the citizens commuting to and from work. The average noise level was over 66 dB and the maximum level was more than 101 dB [Mehdi et al. 2011].

The road noise also influences the habitats of many animals, their walking and communication trails – distorting, i.a., the possibility of birds' communicating [Polak 2014].

It was concluded that a proper design plan of a modern city, created by urban planners, taking into account the specificity of the acoustic environment, has an effect on the decrease of the noise level or even its elimination [Raimbault and Dubois 2005]. Currently, the urban planners are able to foresee the influence of noise in the city already at the stage of designing a street or an intersection, using special, prognostic software for acoustic optimisation [Quartieri et al. 2015].

In Poland, in ca. 20% of living areas, the level of noise is greater than 60 dB. Overall, ca. 33% of the country's population is at risk of being exposed to excessive noise caused, above all, by road traffic [Łukasik et al. 2013]. The permitted levels of environmental noise in Poland are shown in Table 1 [Announcement… 2014].

For the past few years, the municipal authorities of Lublin have been trying to resolve the problem of traffic noise, among others by developing and implementing the programme for the protection of the environment against noise [Environmental protection program…, 2009]. This programme has defined the direction and scope of the actions necessary to restore the permitted environmental levels of noise created due to the use of roads, railway lines and industrial plants.

The purpose of this paper is to discuss the system of road traffic noise measurement, present the results of these measurements and indicate the methods of limiting the excessive noise in Lublin.

ROAD TRAFFIC NOISE MEASUREMENTS

The road traffic noise measurements constitute an important piece of information on the condition of the environment and are useful in the process of creating acoustic maps as part of the strategic plans for environmental protection. The effects of noise monitoring show the direction of implementing remedial actions. First and foremost, they allow to be indication of places where the noise level is significantly exceeded, enabling to introduce, i.a., noise barriers, in order to improve the comfort of the city's population [Boczkowski 2016].

The Voivodship Inspectorate for Environmental Protection is responsible for the environmental noise measurements in Lublin. The tests of road traffic, railway and industrial noise in Lublin were conducted in 2012. They should have been repeated in 2017, but were abandoned due to a number of new road investments in the city.

The measurements are carried out using the referential method, in accordance with the requirements of the Regulation of the Minister for the Environment of 16th June 2011 [Regulation… 2011]. This method is used for measuring the value of noise levels introduced into the environment expressed with L_{DWN} (for the day-evening-night time) and L_N (for the night time) indices, where:

- L_{DWN} – long-term, average A sound level expressed in decibels (dB), determined during all days of the year, taking into account the time of day (from 6 a.m. to 6 p.m.), time of the evening (from 6 p.m. to 10 p.m.) and the time of night (from 10 p.m. to 6 a.m.)

Table 1. The permitted levels of environmental noise in Poland [Announcement… 2014]

Item No.	Area type	Permitted noise level in [dB]			
		Roads and railroads		Other structures and activities being the source of noise	
		during the day (16 h)	at night (8 h)	during the day (8 h)	at night (1 h)
1	a) Resort protection zone b) Hospital areas outside the city	50	45	45	40
2	a) Single-family residential areas b) Residential areas connected with constant or temporary stay of children and youth c) Areas of public nursing homes d) Areas of hospitals in the city	61	56	50	40
3	a) Multi-family and collective residential areas b) Smallholding areas c) Recreational and leisure areas d) Residential and service areas	65	56	55	45
4	Downtown areas of cities with population above 100,000	68	60	55	45

- L_N – long-term, average A sound level expressed in decibels (dB), determined during all times of the night in the year (from 10 p.m. to 6 a.m.).

An example of a measurement device is the AZ8921 sonometer with the sound intensity measurement range from 30 to 130 dB, work frequency from 0.0315 to 8 kHz, resolution of sound intensity measurement of 0.1 dB, and the precision of measurement of 1dB. The measurements are done in designated measurement points, in day- and night-time.

Mobile measurement systems, which are fully automated and consist of a transport vehicle and measurement station, were used to measure the noise intensity in Lublin. The systems are also equipped with the software responsible for the control of the station, collecting measurement data, analysis and presentation of the measurement results, and for creating acoustic maps using specialised software. The acoustic map is used in planning the remedial actions which make the adjustment of the noise level to the required environmental quality standards possible.

The acoustic map of Lublin was elaborated with the calculation and measurement methods, using specialised LimA software by Bruel & Kjaer, with the initial data in the form of a 3D model of the structures, a numeric terrain model, and a satellite orthophotomap. The model obtained in this way was then calibrated on the basis of the acoustic data which came from the measurements of the sound level determined using the noise indices measured in 22 measurement points relating to the vehicle traffic noise emission, 5 points relating to rail traffic, as well as the noise emitted by 12 industrial plants in the city. Two maps with day-evening-night time (L_{DWN}) and long-term night (L_N) indices were elaborated for the noise coming from all the afore-mentioned sources, i.e. vehicle, rail and industrial.

The utilised mobile noise measurement systems, along with the software, were purchased by the Chief Inspectorate for Environmental Protection and co-financed by the European Union funds under the Infrastructure and Environment Operational Programme [www.wios.lublin.pl].

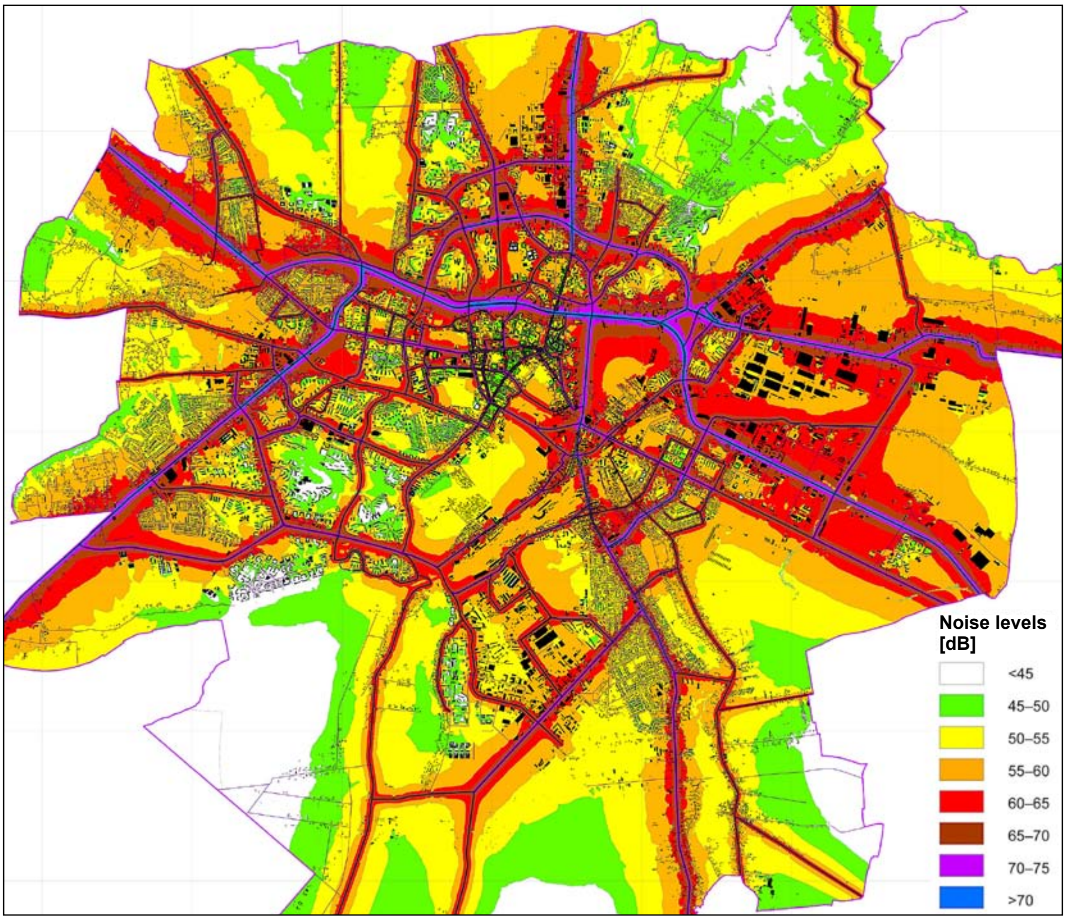

Fig. 1. Day-time acoustic map of Lublin [Acoustic map..., 2012]

NOISE MEASUREMENT RESULTS AND DISCUSSION

The results of the noise measurement in Lublin show that its greatest emitter is the road transport during the day (Fig. 1), rail transport and industrial plants [Acoustic map…, 2012].

The measurements of road traffic noise showed that the permitted standards were exceeded in some measurement points in Lublin. For example, at ul. Krańcowa, the standards were exceeded by 3.8 dB during the day and by 6.9 at night. The highest instantaneous values of the noise emitted to the environment reached up to 90 dB.

In accordance with the environmental protection programme, the *M* index was determined which is the function of the number of citizens and the noise level excessiveness degree [Environmental protection program…, 2009]. This index pertains to the residential housing areas and has the value of zero, when the permitted noise levels are exceeded for the residential structure in question, located in the city. The greater the *M* index, the greater the need to implement the noise prevention actions. The acoustic map of the city contains the information on the *M* index value for each of the residential buildings. On the basis of this information, two zones were differentiated in Lublin, where the noise coming from the identified sources exceeded the permitted level. The 27 zones characterised by excessive impact of road traffic and 5 zones encompassing the impact of the railway transport were distinguished (Fig. 3).

On the basis of the calculated values of the *M* index, it was determined that the most urgent need is the noise protection of the entire city centre (*M* = 5124) and residential buildings at Al. Sikorskiego (*M* = 1319), ul. Szeligowskiego (*M* = 1258) and Al. Racławickie (*M* = 1003). In the city centre of Lublin, the permitted noise levels were found to be exceeded by up to the value of 12 dB, while the proposed remedial actions include the installation of wood joinery with high acoustic insulation (> 40 dB). At Al. Sikorskiego, the permitted noise level was found to be exceeded by up to 8 dB (Fig. 4a), thus it is proposed to install 700 metres long acoustic screens (Fig. 4b). On ul. Szeligowskiego, the permitted noise level was exceeded by up to 11

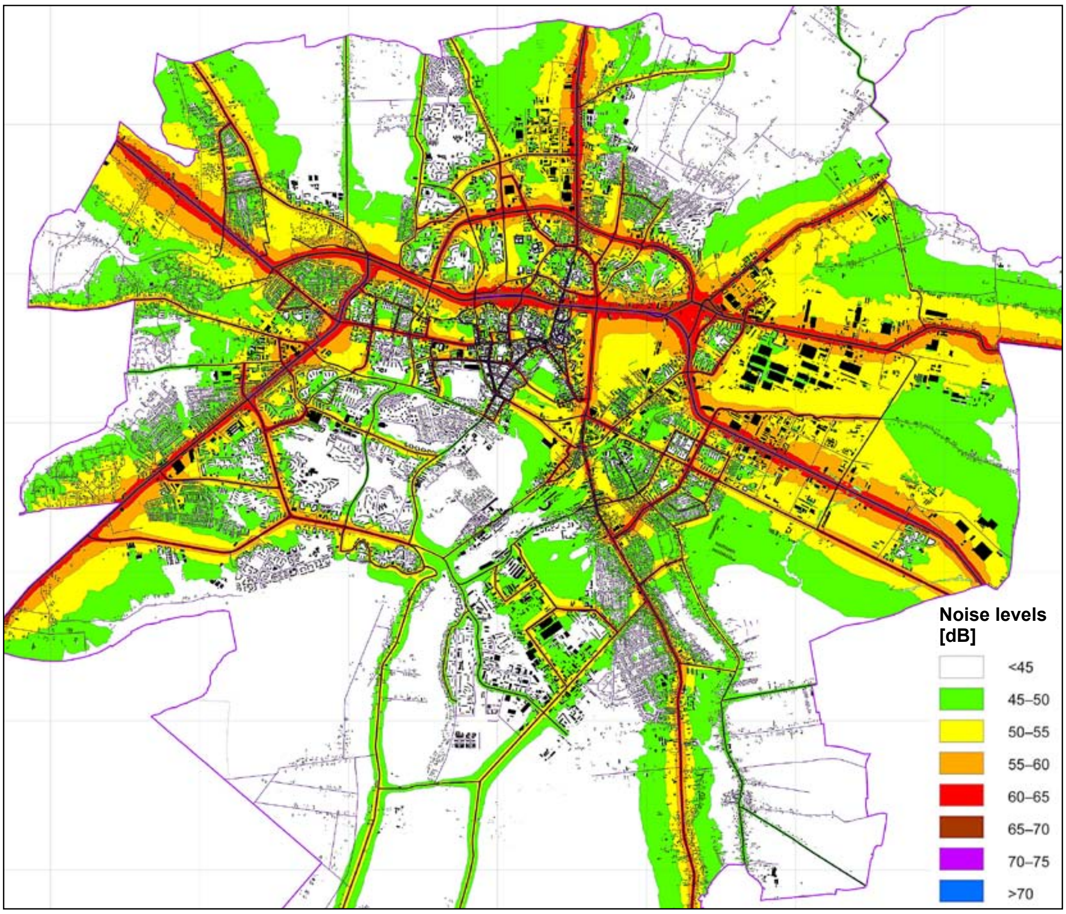

Fig. 2. Night-time acoustic map of Lublin [Acoustic map..., 2012]

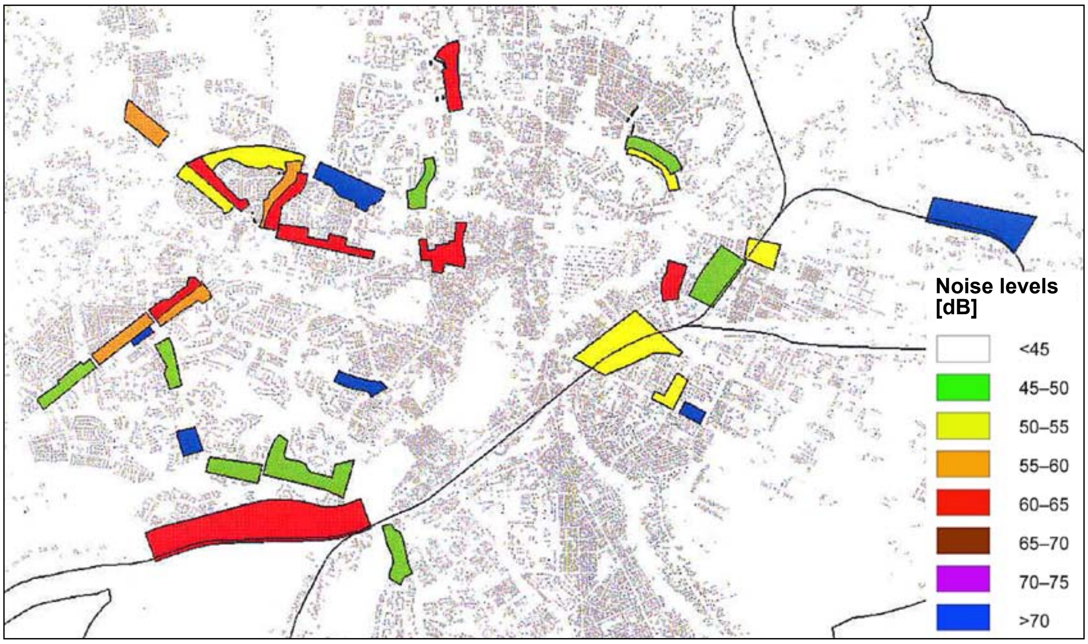

Fig. 3. Residential housing areas in Lublin exposed to road traffic and railway noise to the greatest degree [Environmental protection program…, 2009]

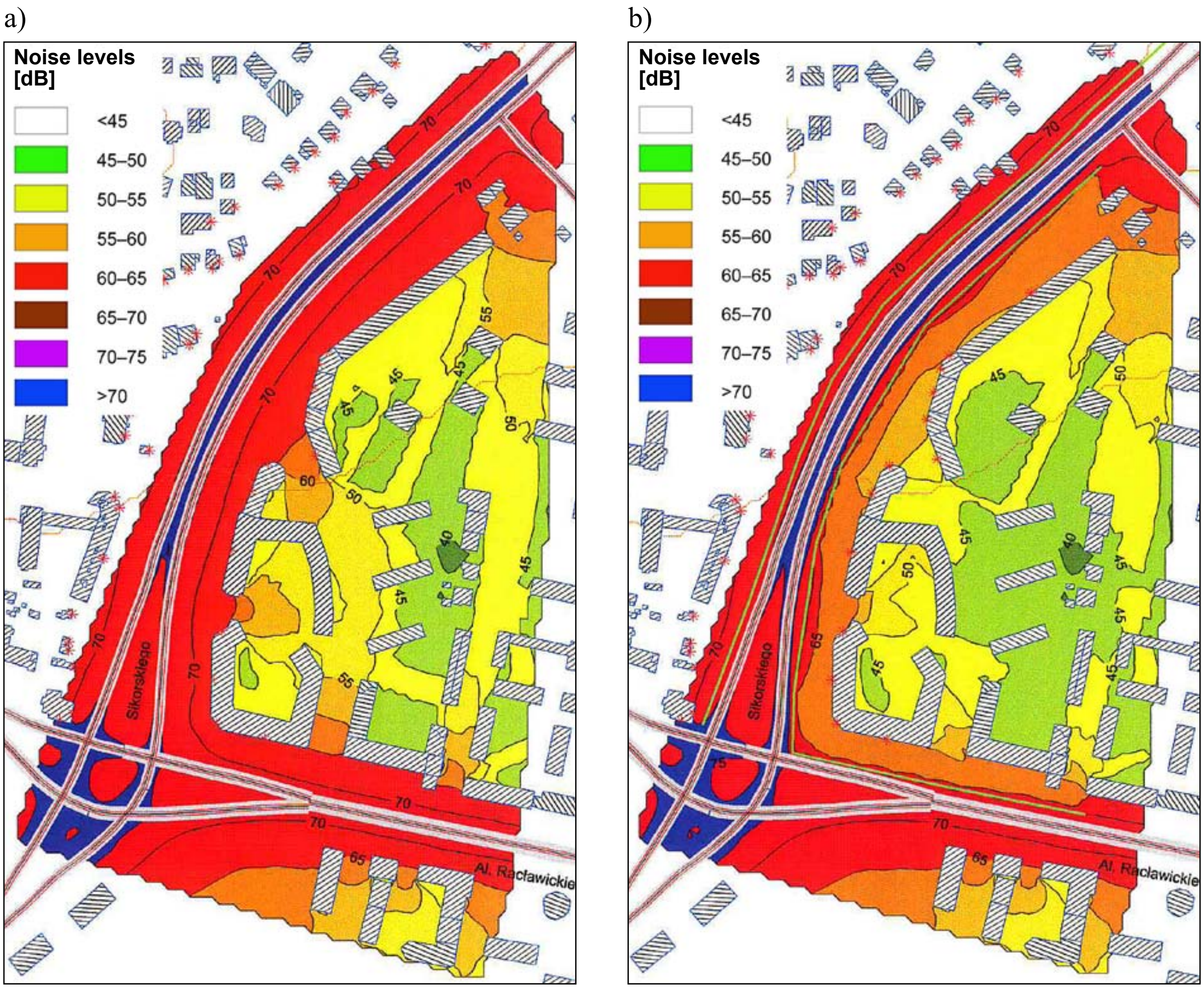

Fig. 4. Map of noise levels at Al. Sikorskiego: a) without acoustic screens, b) with acoustic screens [Environmental protection program…, 2009]

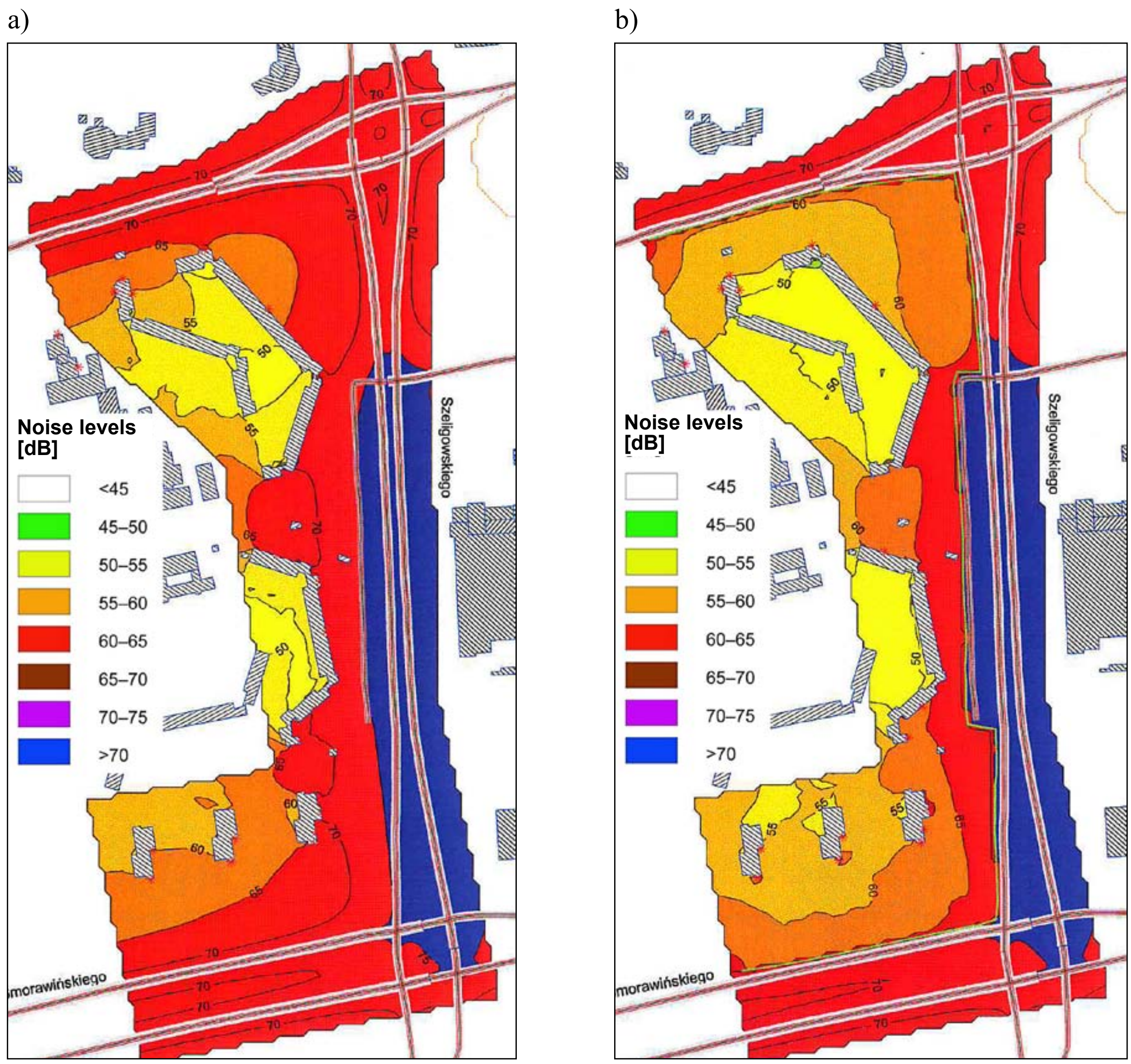

Fig. 5. Map of noise levels on ul. Szeligowskiego: a) without acoustic screens, b) with acoustic screens [Environmental protection program…, 2009]

dB (Fig. 5a), and its reduction will take place after the installation of 1130 metres long acoustic screens (Fig. 5b). At Al. Racławickie, the permitted noise level was exceeded by 7 dB and in order to reduce it is necessary to replace the wood joinery due to the lack of possibility to install acoustic screens.

The M index values indicating the risk of exposure to road traffic noise in the remaining residential housing zones in Lublin were much lower, compared to the above-mentioned examples. The second significant source of noise in Lublin is the presence of a functioning railway, especially on the Warsaw-Lublin line. The calculated M index value was the highest on ul. Wyżynna – M = 1552. The installation of screens with a sound-absorption surface is proposed in the first line of the multi-family residential buildings.

NOISE PREVENTION METHODS AND ACTIONS

The reduction of noise in the city is possible in two ways: by installing the noise protection means and by taking the actions involving proper management of the traffic, its structure or the speed of vehicles. Good results can be achieved by taking into account the proper location of road investments in relation to the residential buildings during the design stage. The most common solutions reducing the noise in urban agglomerations are [Boczkowski 2016]:

- installation of road acoustic screens,
- use of silent surfaces,
- relocation of the traffic from the city to the bypass routes,
- reduction of speed of motor vehicles,

Table 2. Actions for the reduction of noise in Lublin, and the estimated costs [Environmental protection program…, 2009]

Task	Gross cost, PLN/pc
Installation of an acoustic screen (average price level for 1 m^2)	1 000
Purchase and installation of a traffic enforcement camera	200 000
Installation of a measurement point for the 24 h industrial noise level measurement	2 500
Development of a website propagating content connected with the risk of noise and the methods of combatting it	8 000
Installation of an information board cooperating with sound level measurement devices	20 000
Wood joinery replacement	2 500

- reduction of heavy vehicle participation in the overall traffic,
- use of greenbelts around the roads.

In Lublin, the noise protection installations which are most often invested into are acoustic screens, embankments and soundproof screens. Preventive and educational actions are proposed, apart from specific remedial actions. They include:

- expanding urban public transport system as an alternative to individual transport;
- raising social awareness, leading to the change of behaviour in relation to the use of means of transport;
- collecting data on the excessive noise level for the needs of regular updates of the acoustic map of Lublin.

The calculated costs of implementing specific actions for the reduction of noise in the city are shown in Table 2.

An important investment, limiting the noise in Lublin, was the commissioning of the city bypass in December 2016. Its task was to divert the transit traffic outside the city centre, which traffic was calculated to generate 20% of the urban traffic, half of which was arriving from and leaving for Warsaw. Favourable conditions were created in Lublin to develop the bicycle traffic (city bike system and new bicycle paths), as an alternative to the automotive transport.

CONCLUSION

To sum up the discussion, it must be concluded that the environmental noise pollution in Lublin is caused mainly by road traffic, and, to a lesser degree, by railway. It was determined that acoustic screens can be installed by the busiest roads, and the beneficial effects of these installations were shown on the example of two busy streets in the city.

Additional actions in the scope of reducing the noise nuisance should include raising the social awareness of the city's population which would lead to the change of habits in favour of alternative means of transport.

An important action to be taken with regard to the reduction of noise is also the performance of regular noise monitoring and updates of the acoustic map of Lublin. Construction of new housing estates can be planned on the basis of the collected acoustic environment data, where the noise level will be significantly reduced, thus improving the comfort of living of the population.

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