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Mapping of Urbanized Territories Noise Level as a Basis for Developing a Complex of Noise-Reducing Measures

Iryna Davydova[1*], Mariia Korbut[1], Myroslav Malovanyy[2], Volodymyr Shlapak[1], Vasyl Mamray[1], Valentyn Korobiichuk[1]

[1] Faculty of Mining and Ecology, Zhytomyr Polytechnic State University, 103, Chudnivska Str., Zhytomyr, 10005, Ukraine

[2] Ecology and Sustainable Environmental Management Department, Lviv National Polytechnic University, 12, Stepana Bandery Str., Lviv, 79000, Ukraine

* Corresponding author's e-mail: davydvairina2@gmail.com

ABSTRACT

In modern conditions of urban areas development, the importance of protection against noise is increasing. Measures to reduce noise levels in the city's districts should be comprehensive and combine both organizational and architectural-construction and engineering-technological measures. To determine the most optimal combination of countermeasures, it is necessary to initially identify the sources of noise, determine their features and parameters. A complete basis for development of a set of noise reduction methods and means can be mapping of noise levels, which visually allows to determine the intensity and direction of sound spreading. One of the districts of Zhytomyr, which is isolated from other parts of the city and is characterized by a developed infrastructure and heavy traffic, was chosen for noise measurements. Measurements were performed in areas characterized by uniformity of placement, coverage of all functional areas and ability to measure the noise level both at the source of its formation and within the residential area. Based on statistical processing of the experimental data cartographic models of spatial spread of noise pollution are developed. According to the results of the research, zones with different levels of noise pollution were identified. The created map allows to choose the most optimal measures to reduce noise exposure, taking into account the characteristics of each residential area. The design noise level was determined taking into account the measures and noise map was created. The estimated efficiency of the developed measures allows to reduce the total noise level inside the district by 7–8 dB.

Keywords: noise, noise pollution, noise map, noise protection screen, noise level.

INTRODUCTION

In modern conditions of development in urban areas, the importance of noise protection is increasing. Due to the growth of number of vehicles (which are the main source of noise), the industrialization of cities, the growth of transport mobility, the growth of technical equipment of the urban economy, the levels of noise pollution are increasing (Shumove zabrudnennia, 2017).

Rural and urban areas are actively affected by highways and railways, airports and ports. The sources of noise can be railway junctions and stations, large bus stations and companies, motels and campsites, industrial facilities and the construction industry, power plants, etc. Imperfect planning of cities, placement of noise sources in them also create additional noise pollution (Maslov, 2002).

Noise pollution has always been considered a less dangerous form than, for example, chemical or electromagnetic pollution. Usually people do not care how noise affects their health. However, according to research by some governmental and non-governmental organizations (such as the UK's Bureau of National Statistics), noise levels in European cities have increased 10–15 times over the last 20 years (Pignier, 2015; Tkachyshyn, 2014).

Recently, the average noise level from transport has increased by 12–14 dB, and volume has increased 3–4 times. On the main highways of large cities, the noise level exceeds 90 dB and increases annually by 0.5 dB (Boer and Schroten, 2007; Reshetchenko, 2018).

Noise that occurs on the roadway of the highway extends not only to the area near the highway, but also to residential buildings (Bychkovskyi, 2014). Thus, in the zone of the strongest noise are parts of microdistrict and microdistrict located along highways of citywide importance. Noise level measured in living rooms with open windows facing the specified highways is only 10–15 dB lower than near the highways (Sound walls & Acoustic screens).

Activities of this type include the replacement of noisy processes by silent, shock processes by non-shock ones, for example, the replacement of riveting by soldering, forging and stamping by pressure processing; replacement of metal in some parts with non-sound materials, application of vibration isolation, mufflers, damping, acoustic enclosures, etc. (Bakulich, 2016). In some cases, noise reduction is achieved by the use of porous sound absorbing materials coated with perforated aluminium sheets, plastics.

Architectural planning and construction activities are of great importance in noise control (Abramov, 2016). The architectural and planning aspect of noise protection is related to the need to take into account the requirements of noise protection in planning and development projects of cities, towns, districts and microdistrict (Fig. 1). Noise reduction is provided with the use of noise protection screen, territorial gaps, sound protection barriers, zoning of protected sources and objects, noise reduction tree strips. Acoustic means of noise protection divided into means of sound insulation, sound absorption and noise mufflers Figure 1 (Tekhnichni bariery, Ismail, 2009).

Thus, the problem of noise pollution is quite important nowadays. The number of noise sources is increasing every day and it is necessary to apply new means of sound protection. Moreover, given the negative impact of noise on living organisms, this issue needs attention and immediate solution from both society and government (Bies and Hansen, 1996).

Under modern conditions, noise control is a technically complex, comprehensive and expensive task. It is important to reduce noise at the source, to create silent or low-noise machines and processes, vehicles and industrial equipment, starting from the design stage of them (Kucherenko, 2013). However, much more often it is necessary to solve the opposite problem. The gradual increase of noise causes exceeding of the normative noise level in already built districts of cities, with the formed infrastructure. In such

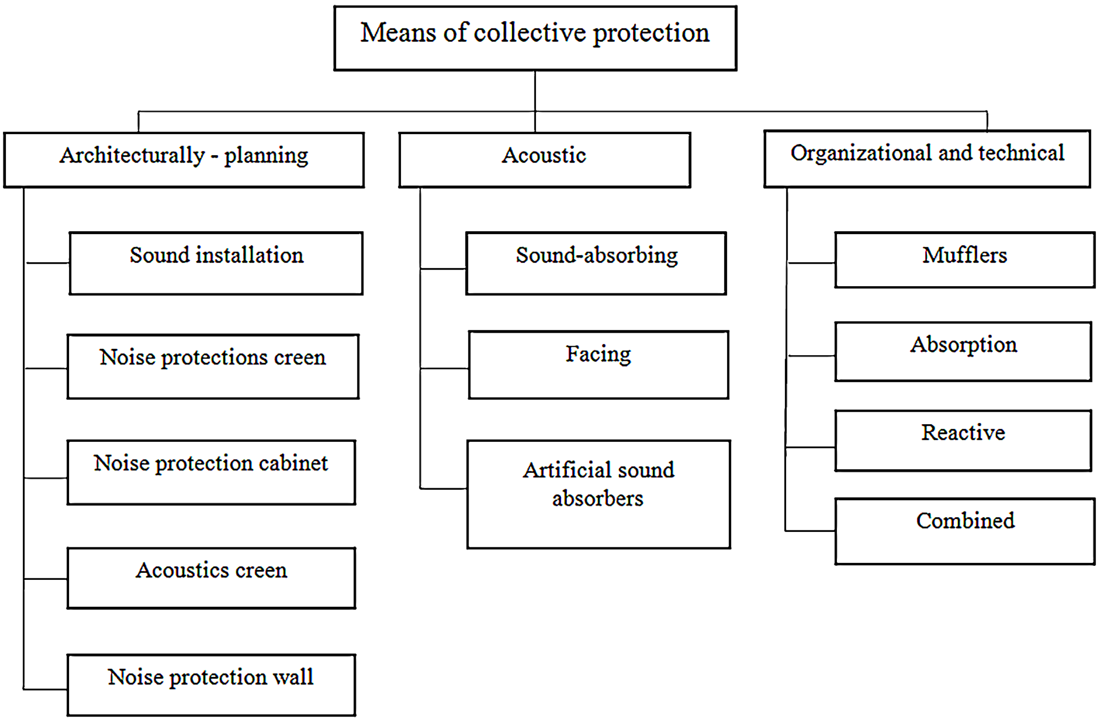

Figure 1. Means of noise protection

cases, it is necessary to use such means as noise protection screen, landscaping, etc., which protect against noise, creating obstacles to its spread (Zaets and Kotenko, 2017). For proper planning of such measures, it is necessary to first investigate the noise level on the specified area, identify the main sources of noise that cause it, calculate the effect of various measures to reduce noise and only then work out a general plan for noise protection (Kliučininkas and Šaliūnas, 2006; Bennett and King, 2010).

STUDY AREA

The purpose of the work is to study the noise level and develop a set of measures to reduce noise in Khmilnyky district of Zhytomyr, Ukraine.

As it is quite difficult to cover the territory of the whole city, the noise level assessment was determined in one of the districts of Zhytomyr, namely Khmilnyky district. Khmilnyk used to be a district near the city of Zhytomyr, now it is a district of the city with a small number of buildings. The largest traffic flow is on Suryna Hora Street, Hlybochytska Street, Zarembskoho Square and Polsky Boulevard (Fig. 2)

Khmilnyky district was selected for research taking into account the following factors:

- the neighborhood is remote from the city center and partially surrounded by a green zone, which reduces probability of other adjacent areas impact with significant traffic flow on the formation of the noise level;
- a significant number of the population lives on the territory of the district, which causes a high level and variety of noise sources;
- uneven construction, infrastructure and landscaping of the district allows determining the main factors that affect the sound wave propagation;
- low density of housing makes it possible to design additional means to reduce the noise level on residential buildings and adjacent areas.

METHODS AND MATERIALS

The research consisted of several stages in accordance with the general research program (Fig. 3).

Research of the noise level of Khmilnyky district can be conditionally divided into two interconnected parts:

- measurements of acoustic parameters, which were carried out throughout the district with the same distance between the measurements points;
- processing of the obtained results with the subsequent noise maps design.

Based on the area survey of Khmilnyky district, key places were identified, in which noise measurements were then carried out.

The main requirements for the studied areas are the uniformity of buildings, coverage of all functional areas and the possibility of parallel measurement of noise near its source and behind the "sound screen" (inside the residential area).

The ADA ZSM 130+ digital noise meter (Shumomir) was used for measuring noise. The noise meter is designed to work on safety, health, industrial safety and sound quality control in various conditions. The device allows: to measure the noise level in the range from 35 to 130 dB in the

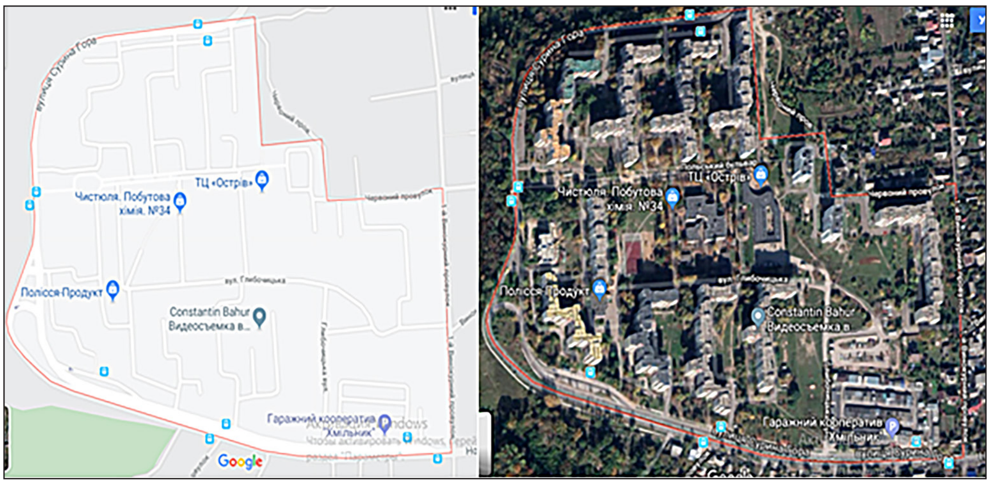

Figure 2. Study area

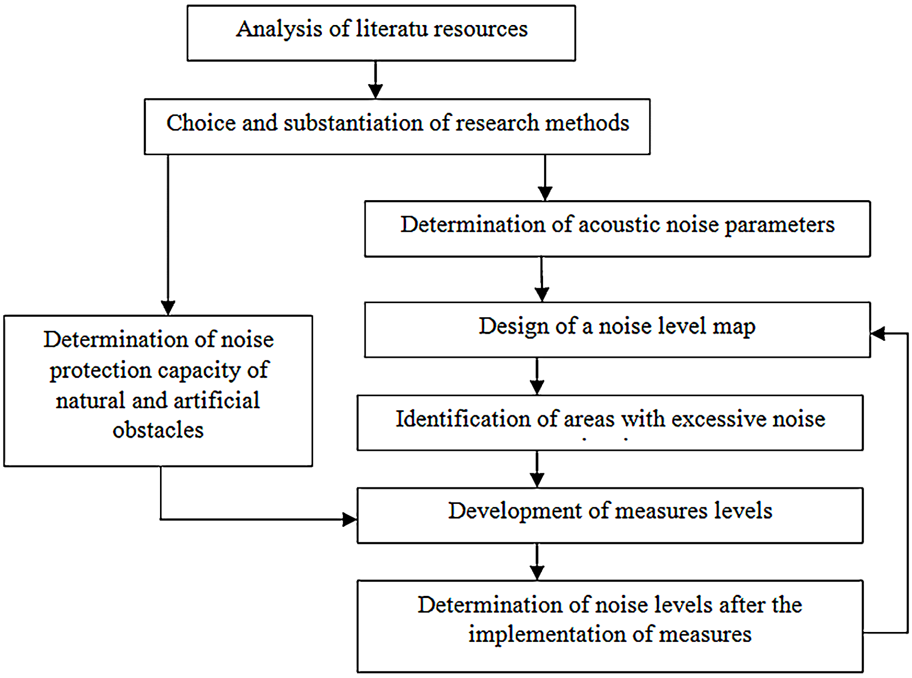

Figure. 3. Research program

range of 31.5 Hz – 8 kHz, to measure the sound pressure level on the A / C frequency, to perform a temporary measurement (fast 125 msec., 1 sec.), To transmit data to the recorder, keep the maximum measured value, save the measured value (HOST 31296.2-2006).

The final stage of the project was the development of measures to reduce the noise level in residential buildings and adjacent areas, determining the project noise level taking into account the measures and creating a project noise map.

The noise map of the residential area includes:

- updated scheme of noise sources with indication of calculated noise levels;
- noise maps of microdistricts and other areas that are part of the residential area;
- map of acoustic discomfort of the residential area;
- the main urban ways to reduce noise to the regulatory level.

RESULTS AND DISCUSSION

The starting points of the research were the following objects: Hlybochytska Street, Suryna Hora Street, Zarembsky Square and Polsky Boulevard, the shopping centre “Island”.

Based on statistical processing of the received experimental data cartographic models of spatial spreading of noise pollution within the microdistrict are developed.

Figure 4 shows the general scheme of noise level measurements in the district of Khmilnyky. Noise measurement points evenly cover the district. Measuring points are set at the minimum distance from the main source of pollution (the route that covers the district).

After surveying the area and selecting research points, the noise level was measured, and according to the obtained data, a map was developed showing the current noise level for the study area (Fig. 5).

The created map shows that the highest noise level is observed near places where cars go to the lanes of the main road. There, the noise level reaches a critical level. In the middle of the district, where there are residential buildings and limited traffic, the noise level is the lowest and meets almost all indicators of life safety standards.

The obtained research results clearly show that the main source of noise is road transport, which creates a noise level of 73–91 dB. In Khmilnyky district of Zhytomyr, all modes of transport create approximately the same noise level during their operation. The situation is not getting better even with the advent of electric cars, as their number in the general flow is low.

The activity of car flows and crowds influence the dynamics of changes in the noise level. For example: along roads during working hours and on Sunday morning the noise level is higher than on Sunday evening; near public institutions on weekdays the noise level is higher than on weekends; near the supermarket the noise level does not change.

The current regulations (Sanitary standards of permissible noise in residential buildings and residential areas (HOST 23337-2014) set permissible sound pressure values of maximum and equivalent noise levels. For areas near residential buildings during the day (from 8 to 22 hours), the equivalent level should not exceed 40 dB, and the maximum should be 75 dB. At night (from 22 to 8 o'clock), these levels should not exceed 45 and 60 dB, respectively.

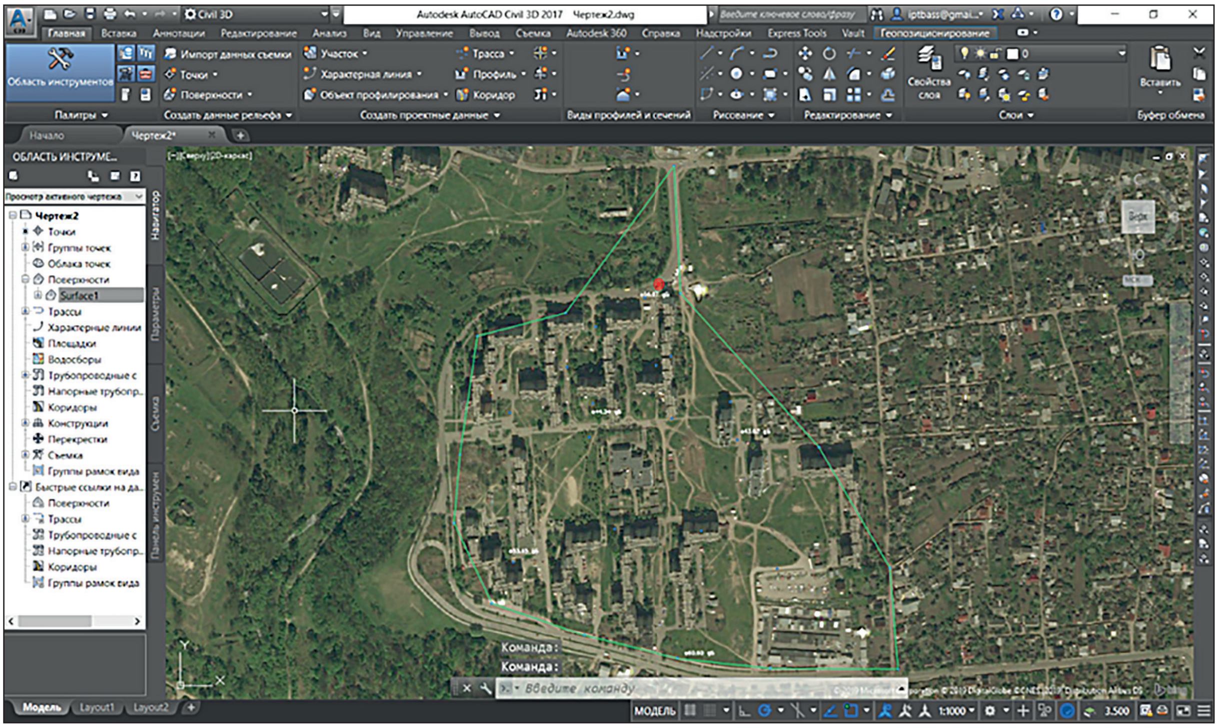

Figure 4. Coordinates of noise measurement points

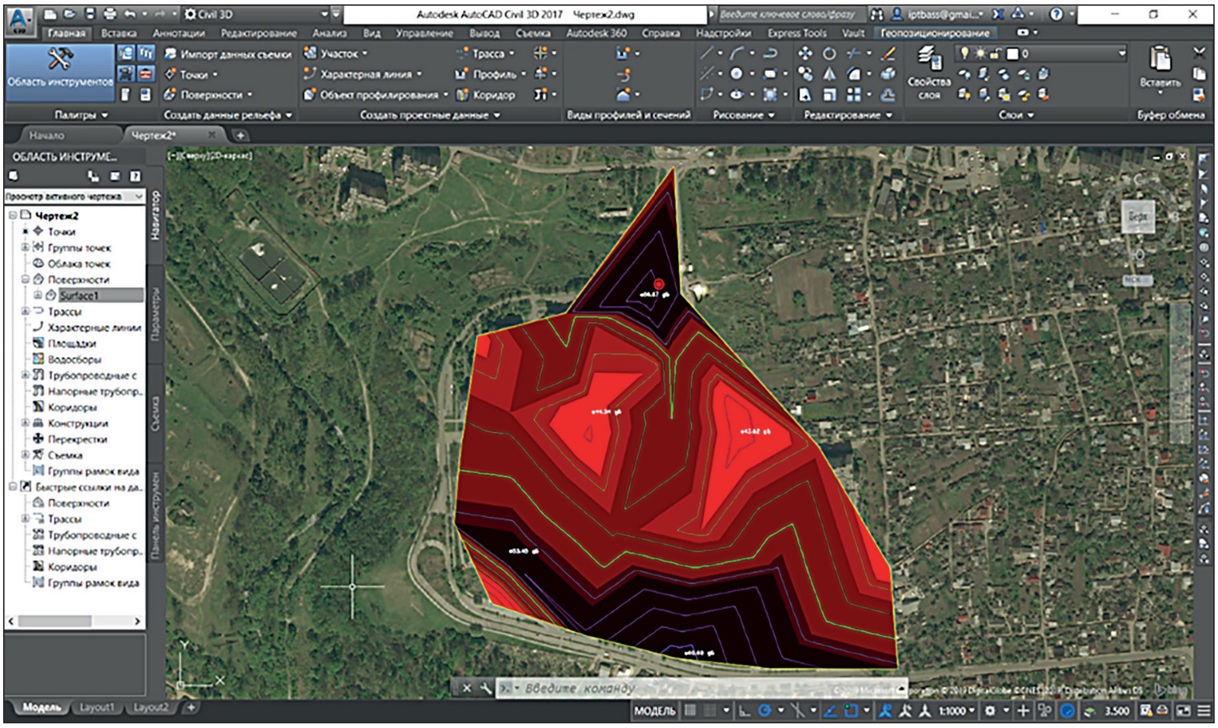

Figure 5. Map of noise level in Khmilnyky microdistrict

From the obtained data, we can conclude that the noise level in the central part of the district is within normal limits. This is directly because the district is small and infrastructurally underdeveloped. However, areas directly adjacent to highways have a high noise level and require measures to design noise-reducing structures and elements.

Noise pollution on the section of Polish Boulevard was analysed. When leaving on the main Surina Gora Street, the noise level varies from 54 dB to 65 dB. Then the traffic flow accelerates at a distance of 100–150 m, after leaving the turn and the noise level increases, because the maximum noise level from vehicles is created during acceleration. Vehicles can also create a significant level of noise when driving at high speeds (this occurs at night, when the intensity of traffic is negligible), because it is known that an increase in speed for every 10 km/h creates an increase in noise level of 3 dB.

The noise level on the streets directly adjacent to residential buildings was determined (Table 1). Comparing the noise levels in the morning and afternoon, it was found that at rush hour, the noise level from vehicles is on average 75.85 dB, which exceeds the allowable level. The highest noise level in the morning on Surina Gora Street is 80.4 dB. This is directly because this street is the main one and runs along almost the entire district. From 3 to 4 p.m., when the intensity of traffic during working hours is the lowest, respectively, the noise level is much lower.

Table 1. Noise level on the streets of Khmilnyky district

Street	Measurement time	
	8.00–9.00 a.m.	3.00–4.00 p.m.
Suryna Hora Street	80.4	60.1
Hlybochytska Street	77.4	58.0
Polsky Boulevard	70.4	45.2
Zarembsky Square	75.2	57.5

Determination of the level of noise pollution was carried out on the territory of the shopping center "Island", which is characterized by the largest concentration of people. Noise level measurements were performed 3 times a day (at 8.00 a.m., at 2:00 p.m. and at 6.00 p.m.), because the noise level is different at different times of the day. During the study, it was found that the highest noise level reached 82.9 dB (Fig. 6).

Figure 6 shows that the highest noise levels on weekdays are observed in the morning and evening, because it is at this time that a large number of people leave and return from work. The cause of such noise level is not only vehicles (road noise) but also the noise from crowds. At lunchtime, the noise level is mostly within the permissible limits of the State Sanitary Norms (60 dB). On weekends, the noise level near the shopping center "Island" is the lowest.

The development of measures to protect urban areas from noise can be done in their both design and reconstruction. However, if the infrastructure of territories is already formed, the most effective way

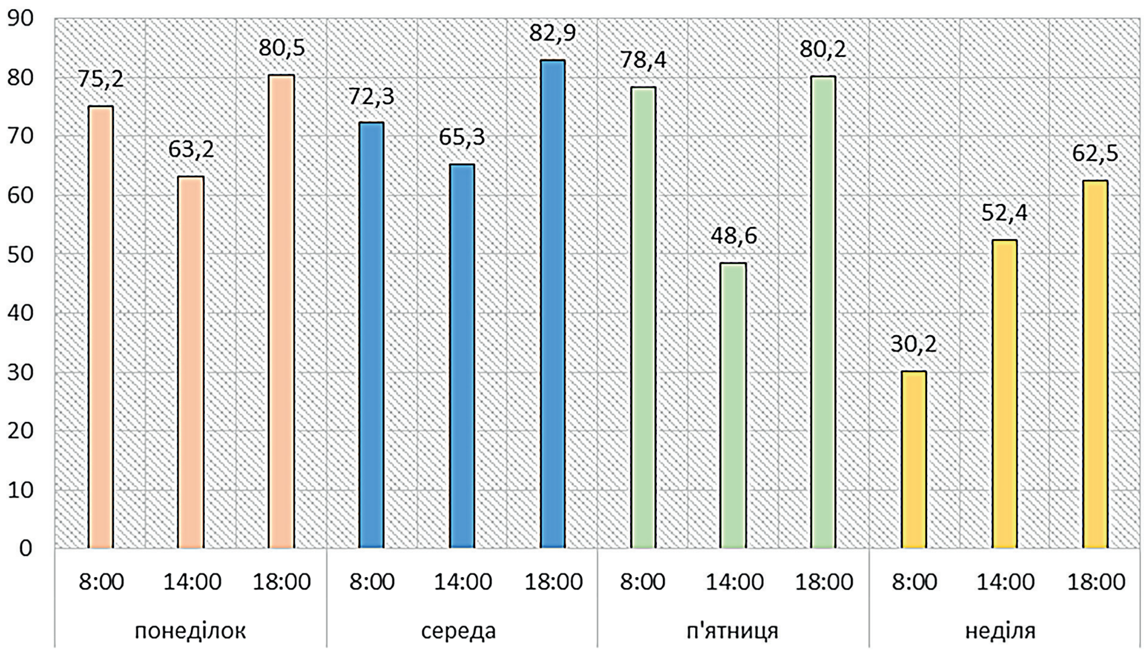

Figure 6. Noise level near the shopping center "Island", dB

to reduce noise is to install noise protection screens. The design solution and geometric parameters of noise protection screens are selected in each case individually. When choosing them, one of the defining criteria is a rational ratio of "cost - efficiency".

Figures 7–9 show the expected sound fields in the adjacent territory with a noise protection screen: 7 m high and 100 m long (variant 1) (Fig. 7), 7 m high and 150 m long (variant 2) (Fig. 8), 8 m high and 150 m long (variant 3) (Fig. 9).

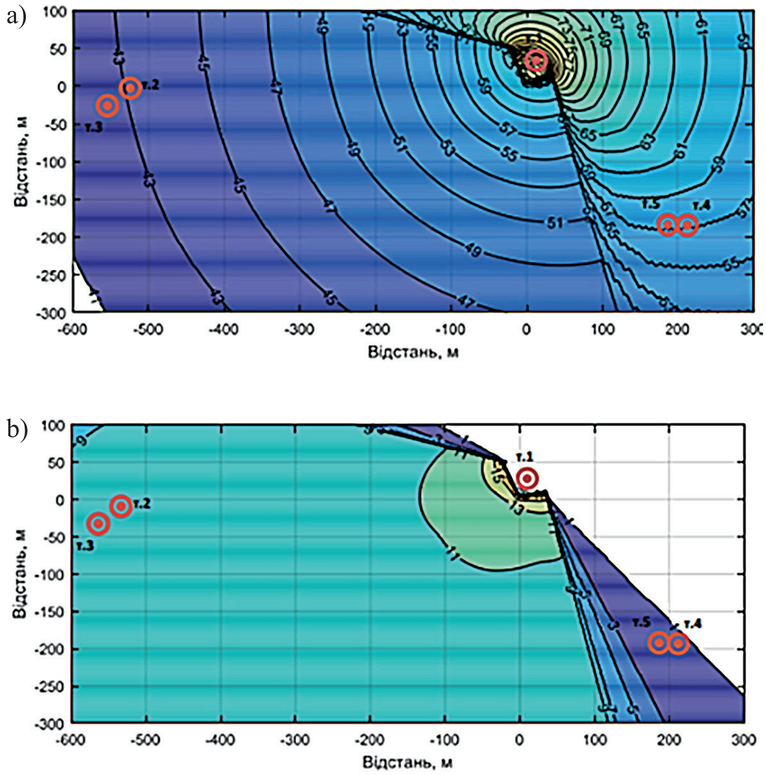

Figure 7. Screen version 1 (noise protection screen height 7 m, total length 100 m)

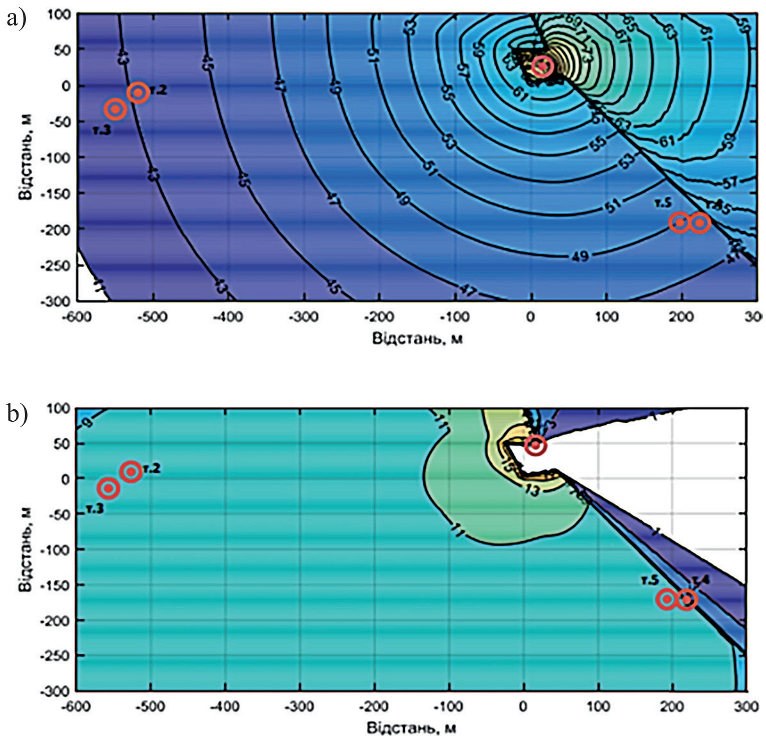

Figure 8. Screen version 2 (noise protection screen height 7 m, total length 150 m)

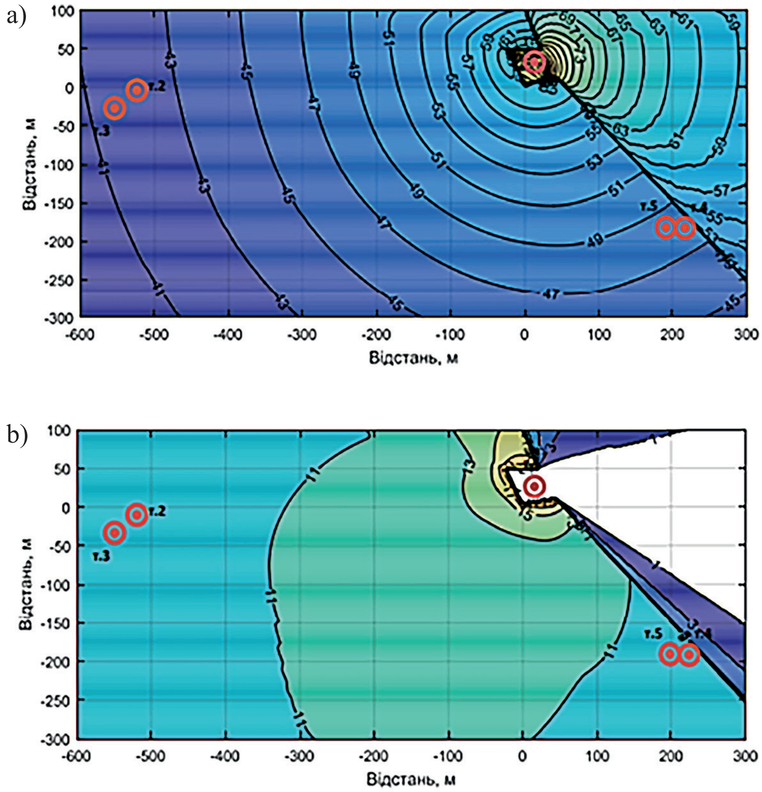

Figure 9. Screen version 3 (noise protection screen height 8 m, total length 150 m)

Figure 7 shows the expected sound field with the noise protection screen with height 7 m, the screen is located along two sides of the site with a length of 45 m and 45 m. This noise protection screen location allows obtaining some noise shielding in the directions of residential buildings. However, the noise map shows that the length of the noise protection screen is insufficient and sound penetrates not only through the upper edge of the screen, but also from the side.

Figure 8 shows the expected sound field and the efficiency of the noise protection screen with height of 7 m, with location of the noise protection screen along the three sides of the concert venue Fig. 8(a). Increasing the length of the screen led to an increase in its efficiency, which has resulted in a decrease in noise levels near a residential building on Polsky Boulevard, 85/5 by up to 8 dBA compared to option No. 1.

Figure 9 shows a variant of the noise protection screen 3 with a height of 8 m and the same screen configuration as in the variant №2. Increasing the noise protection screen height has reduced the noise levels near residential buildings by 1 dB.

Thus, the analysis of possible noise protection screen variants showed that for Khmilnyky district of Zhytomyr location of the noise protection screen according to option 1 will be inexpedient (Fig. 10), as this noise protection screen variant has insignificant noise absorption capacity and will not be able to reduce the noise level to the permissible level. The noise protection screen according to option 3 is effective (Fig. 11). It protects the area directly next to residential buildings. Therefore, this option was taken as a basis for further research and analysis.

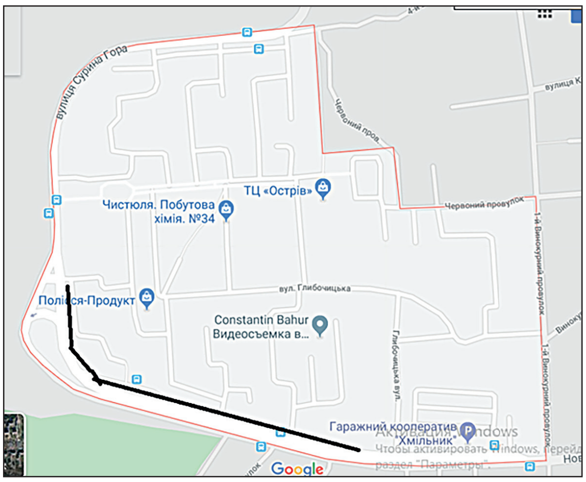

Figure 10. Location of the noise protection screen in Khmilnyky district according to option 1

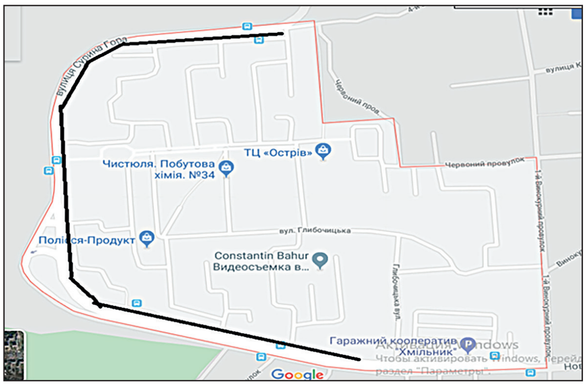

Figure 11. Location of the noise protection screen in Khmilnyky district according to option 2 and 3

The location of the noise protection screen according to option 3 allows reducing the noise levels in the area adjacent to the noise source by 10–15 dB. However, such values are only possible if there is one screened noise source, for example when noise screening traffic on a long-distance highway. In the conditions of the city district, vehicles are the main, but not the only source of noise. Using the noise protection screen from transit vehicles will significantly reduce the noise level, but will not in any way reduce the noise caused by traffic within the district, lives of local residents, work of the infrastructure of the district. The calculations show that the average noise with using the noise protection screen will decrease by 7–8 dB (Fig. 12). When moving further into the district, the noise level will decrease, but the difference between its level before and after the using of the noise protection screen will not be as significant as near the highway due to noise from different sources and reduce traffic noise to the overall noise level.

Analyzing the design values of the noise level it is concluded that the noise protection screen will reduce the noise level and bring it in line with standards for almost the entire study area. Exceptions are the exit to Klosovsky Street, which is not part of the district and therefore not subject to the design of protective measures and Glymbochytska Street, which is the main place of entry of vehicles into the district and cannot be shielded by a solid noise protection screen. In addition, this area contains virtually no landscape shielding elements. It is flat with a small number of trees; the buildings are located further into the district and are placed perpendicular to sound waves.

Therefore, for this part of the district, in addition to the installation of the noise protection screen, it will be appropriate to landscaping the area with planting trees that have significant noise-absorbing properties: maple, linden, etc. (Zeleni nasadzhennia). However, it should be borne in mind that it takes some time for trees to reach the required size, and even after the relevant measures are taken, the normative noise level in the district will not be reached immediately.

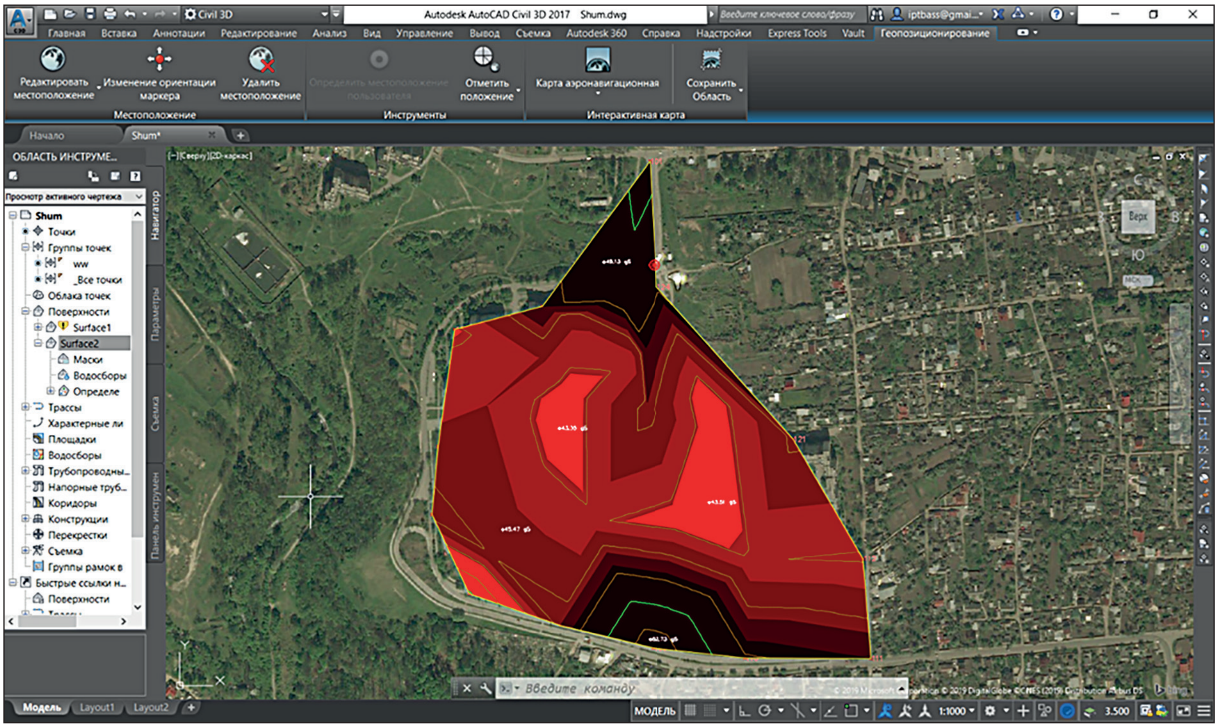

Figure 12. Designed map of noise level in Khmilnyky district after installation of the noise protection screen

CONCLUSIONS

Reduction of noise from vehicles is provided in various ways, including architectural and acoustic. The practice of noise control shows that the noise protection screen installed along highways are an effective and high-quality means of protection.

According to the calculated results, residential areas with excessive noise levels were identified. Therefore, it is suggested that the noise protection screen be installed around the area as an effective and only possible means of reducing noise.

Noise characteristics of the traffic flow were calculated and the noise map was designed in the Khmilnyky district.

Taking into account necessity of installation the noise protection screens, their overall efficiency is 7–8 dB. The combination of engineering and technical solutions with landscaping of the district will reduce the total noise level in the residential area at 10–13 dB in the future (in 10–15 years).

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