Ecological Questions 33 (2022) 3: 99–121 http://dx.doi.org/10.12775/EQ.2022.021

Case study of noise pollution from vehicles and legal mechanisms for road noise control

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Received: 16 April 2022 / Accepted: 5 May 2022

Abstract. Among the many environmental problems of the modern world one of the important ones is noise pollution. Currently, noise pollution from vehicles requires special attention in densely populated and industrial cities, as there is a trend towards an increase in the areas of acoustic discomfort in built-up areas. The noise that occurs on the roadway of the highway extends not only to the territory near the highway, but also deep into the housing development. Study' objective was to assess noise pollution from vehicles in the most densely populated area of Poltava (Ukraine), as well as to establish the possibility of influencing the situation through legal mechanisms to have an understanding of further research directions and ways to achieve a comfortable urban environment in Ukraine. The noise levels from traffic flows were measured in accordance with GOST 20444–2014, using the Testo 815. To determine the equivalent noise level from the traffic flows movement, an empirical dependence was applied in accordance with the methodology of the State Agency for Highways of Ukraine. Determined that the daytime threshold values are exceeded by 20–28.9 dB(A), which is not acceptable. The reasons for the increase in noise are the road bumps, a significant number of cars and number of stops and streets junctions, the movement of vehicles at a non-constant speed, lack of roadside landscaping. About 62,550 people live in areas where the noise level exceeds the permissible value for the area near residential buildings. The calculation method used turned out to be more accurate than the measured results and showed a significant effect of traffic intensity on noise pollution. Apparently, the low measurement accuracy is justified by outdated road noise measurement standards, which, in turn, need to be seriously revised. Reducing noise levels by optimizing traffic flows is one of the priority areas in which it is necessary to bring the environmental legislation of Ukraine. Ukrainian legislation still needs to undergo many changes to reach a level where it can be used as a control lever to achieve a safe ecological environment.

Keywords: noise pollution, vehicle, traffic intensity, legal, Poltava, Ukraine.

1. Introduction

Among the many environmental problems of the modern world (Ziarati et al., 2020; Vambol et al., 2019; Mozaffari et al., 2020), one of the important ones is noise pollution (Lauper et al., 2016; Lumnitzer et al., 2018). Noise sensitivity manifests itself through irritation, which can be considered a health-related marker of environmental noise exposure.

Currently, noise pollution requires special attention in densely populated and industrial cities, as there is a trend towards an increase in the areas of acoustic discomfort in built-up areas. Acoustic discomfort zones are areas with sound levels and sound pressure levels that exceed the normative values. One of the factors that create this kind of pollution is urban and suburban transport. Noise pollution from traffic is one of the most pressing problems of our time (Mirzaei et al., 2012; Klepikov et al., 2021). It has been predicted that the burden of noise pollution will increase significantly if the current trends of increased congestion and increased car use in cities continue without proper management (Geravandi et al., 2015). The imperfection of the legislative and regulatory framework, the lack of economic levers for regulating permissible sound levels is the reason for the increase in acoustic pollution of the urban area.

In connection with the growth in the number of vehicles, the growth of the transport mobility of the population, the growth of the technical equipment of the urban economy, contacts between the technogenic environment of the city and the environment are expanding. The physical and psychological effects of loud noises are well documented in studies (Geravandi et al., 2014; Taghavirad & Mohammadi, 2014), but at the same time, it is important to study the level of noise pollution and its impact on health in most densely populated and industrial cities (Geravandi et al. , 2015; Özen et al., 2021).

The reactions of the human body to loud sounds are similar to reactions to imminent danger. Some of these characteristic responses are the secretion of the hormone adrenaline and changes in heart rate and blood pressure (Veternik et al., 2018; Sørensen et al., 2012). Other effects of noise include feeling irritated, headaches (Alkhalawi et al., 2021), irritability, stress (Palma et al., 2019; Kou et al., 2021) and digestive problems (Pyko et al., 2015; Kruzhilko et al., 2020). Noise control is considered an important health issue that will improve the quality of citizens life.

Noise from vehicles depends on many factors: engine power and operating mode, technical condition of the vehicle, tires and road surface quality (Freitas et al., 2018), speed (Paiva et al., 2019).

The noise that occurs on the roadway of the highway extends not only to the territory near the highway, but also deep into the housing development. However, first of all, the noise of the transport highway affects those residents whose apartments or houses are located along the highway.

2. Objectives

The current study' objective was to assess noise pollution from vehicles in the most densely populated area of Poltava (Ukraine), as well as to establish the possibility of influencing the situation through legal mechanisms to have an understanding of further research directions and ways to achieve a comfortable urban environment in Ukraine. This study is one of a number of similar case studies conducted in other countries, but its originality and novelty consists in the view on the current world problem from two sides: technical and legal. Since without a solid legal basis, technical measures to eliminate the environmental problem will not be implemented.

3. Materials and Methods

3.1. Study area

The Shevchenkovsky district of Poltava (Ukraine) was chosen for the study. The district occupies the south-western part of the city, on the right bank of the Vorskla River (Fig. 1). This area is characterized by dense buildings, increased intensity of the traffic flow, active movement of municipal transport and the presence of stops for disembarking passengers. The district is the most densely populated area of the city, where, according to official statistics, 139 thousand people live.

Figure 1. Study area

To measure noise levels, the territory was divided into 151 sections, a measurement program was drawn up, in which the places and time of measurements were assigned. Places for measurements were chosen on straight horizontal sections of a street or highway with a steady speed of vehicles. In addition to determining the noise level, the intensity of the traffic flow was determined, i.e. the number of vehicles moving during a set time interval. Time interval selected 15 min.

3.2. Measurements

The noise levels from traffic flows were measured in accordance with GOST 20444–2014, using the Testo 815 sound level meter, the technical data of which are as follows:

– measurement range – 32…130 dB;
– error – ±1 dB;
– working temperature – 0…+40 °C.
The sound level meter was pre-calibrated.

Each measurement lasted 15 minutes. The microphone was directed towards the traffic flow and located at a height of 1.5 m ± 0.1 m from the level of the roadway coverage. The intervals between readings of sound levels were 5–7 s. The countdown is made during the entire measurement period, both in the presence of vehicles on the site, and in their absence.

The measurements were carried out in good calm weather (in the absence of precipitation, fog), when the surface of the carriageway of the street or highway was clean and dry. There were no additional effects on the measuring equipment and adverse factors.

3.3. Method for determining the equivalent noise level

To determine the equivalent noise level from the traffic flows movement, an empirical dependence was applied in accordance with the methodology of the State Agency for Highways of Ukraine (SAHU), since this methodology was approved at the state level (M 02071168–416:2016). The SAHU ensures the implementation of state policy in the field of road facilities and road management.

The daily traffic intensity was determined by the formula (1):

$$I_d = I^{i}_{hour} K_{red}\,, \quad (1),$$

where I_d– daily traffic intensity, pcs/day; I^{i}_{hour} – hourly traffic intensity, pcs/hour; K_{red} – coefficient of reduction of hourly intensity to daily.

The calculated level of equivalent noise from a public highway is determined in dB(A) by the formula (2):

$$L^{calc}_{tf} = L^{calc}_{sl} + \Delta L_{CarbEn} + \Delta L_{DiesEn} + \Delta L_{as} + \Delta L_{slope} + \Delta L_{rs} + \Delta L_{ds} + \Delta L_{sr} + \Delta L_{db} + \Delta L_{cross} \quad (2)$$

where L_{tf} – calculated sound level from traffic flow, dB(A); ΔL_{CarbEn} – correction taking into account the number of vehicles in the stream with a carburettor engine, dB(A); ΔL_{DiesEn} – correction taking into account the number of vehicles in the traffic flow with a diesel engine, dB(A); ΔL_{as} – correction taking into account the deviation of the average speed on the studied section of the road compared to the speed on the horizontal, dB(A); ΔL_{slope} – correction taking into account the magnitude of the longitudinal slope, dB(A); ΔL_{rs} – correction taking into account the type of road surface, dB(A); ΔL_{ds} – correction taking into account the presence of a dividing strip, dB(A); ΔL_{sr} – correction taking into account the surface cover of the roadside, dB(A); ΔL_{db} – correction taking into account the buildings density in the roadside area, dB(A); ΔL_{cross} – correction taking into account the type of road crossing, dB(A).

The assessment of the environmental safety of the road section in terms of acoustic pollution was carried out in accordance with Table 1 (M 02071168–416:2016).

4. Results

4.1. Road quality, traffic flow and noise level

During the study, damage to the road surface was identified (Fig. 2). For Poltava, the problem of poor-quality, damaged asphalt surface is quite relevant. Potholes in the road are one of the most important causes of traffic noise.

Due to the underdeveloped economy, road services rarely provide current and, even more so, major road repairs. Modern technologies for creating noise-absorbing pavement are also not implemented due to economic instability in the country. Today, scientists have already proposed high-strength coatings that reduce noise (Ribeiro et al., 2021), for example, rubberized asphalt reduces noise by 3–7 dB(A) (Gu et al., 2018; Li et al., 2018), which is equivalent to reducing traffic by 50% or comparable to the construction of a noise barrier (Bernhard & Wayson, 2004). However, at

Table 1. Classification of highways by noise (M 02071168–416:2016)

Noise class	Noise class name	Noise level, dB(A) (7.5 m)	Travel speed (km/h)	Name of roads and streets
I	Low noise roads	Over 55 to 60	up to 40	Passages, park roads, noise-protected streets
II	Roads of increased noise	Over 60 to 65	up to 50	Streets and roads of local significance, main streets of district significance
III	Noisy roads	Over 65 to 70	up to 60…70	Main streets, transport and pedestrian streets
IV	Very noisy roads	Over 70 to 75	up to 80…90	Main streets of continuous and regular traffic
V	Too noisy roads	Over 75 to 80	up to 100…110	Trunk roads, highways
VI	Extremely noisy roads	Over 80 to 85	up to 120	Express roads

Figure 2. Damage to the road surface in Shevchenkivskyi district of Poltava

the same time the durability of the acoustic performance and mechanical properties of acoustic coatings in dense urban traffic over time remains a matter of study (Ribeiro et al., 2021).

The study results of the intensity and composition of traffic flows for 1 hour during the daytime period for different categories of vehicles are shown in Figure 3.

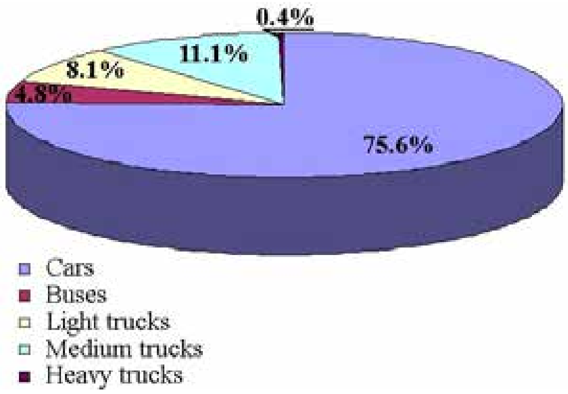

Figure 3. Percentage distribution of vehicle types on the surveyed roads

The largest share of the traffic flow in the selected territory was made up of cars – 75.6%, while buses and trucks accounted for 24.4% of the total number of vehicles. Among trucks, the largest number of medium-duty vehicles was observed. Exactly trucks, in addition to public transport, make a significant contribution to noise pollution (Kulauzović et al., 2020; Zannin et al., 2018). Most of the trucks were recorded at sections 23, 40, 48, 49, 97, 98, 118, 135, which is associated with the maintenance of a large number of commercial facilities located in Shevchenkivskyi district of Poltava and its environs.

At sections 9, 13, 17, 23, 40, 45, 48, 49, 58, 67, 97, 98, 113, 118, 131–133 traffic intensity exceeded 10,000 vehicles (Appendix A, Table A.1). This is justified by the fact that the most popular routes of municipal transport and private transport companies for the transport of passengers pass through these road sections. It should be emphasized that in most cases vehicles for the transport of passengers are outdated and their technical condition does not meet modern standards of developed countries. This contributes to increased noise pollution (Fig. 4).

The most loaded were Sennaya street (section 118), Heroyiv Chornobyltsiv street (section 98), Yevropeyska street (sections 40, 48, 113).

It was found that the lowest noise level is 54.2 dB(A) at section 143 along Vyacheslava Chornovola street, the highest noise was recorded at section 138 along Sobornosti street and at section 145 along Volodymyra Kozaka street, which is 81.6 dB(A) and 83.9 dB(A), respectively. Based on the classification of roads (Table 2), section 143 along Vyacheslava Chornovola Street corresponds to the III noisy class – "noisy roads". It should be noted that in addition to this section, another 57 sections out of 151 also belong to the "noisy roads" class. Class II – "roads of increased noise" – includes 2 sections out of 151, 49 studied sections belong to class IV – "very noisy roads", 39 studied sections belong

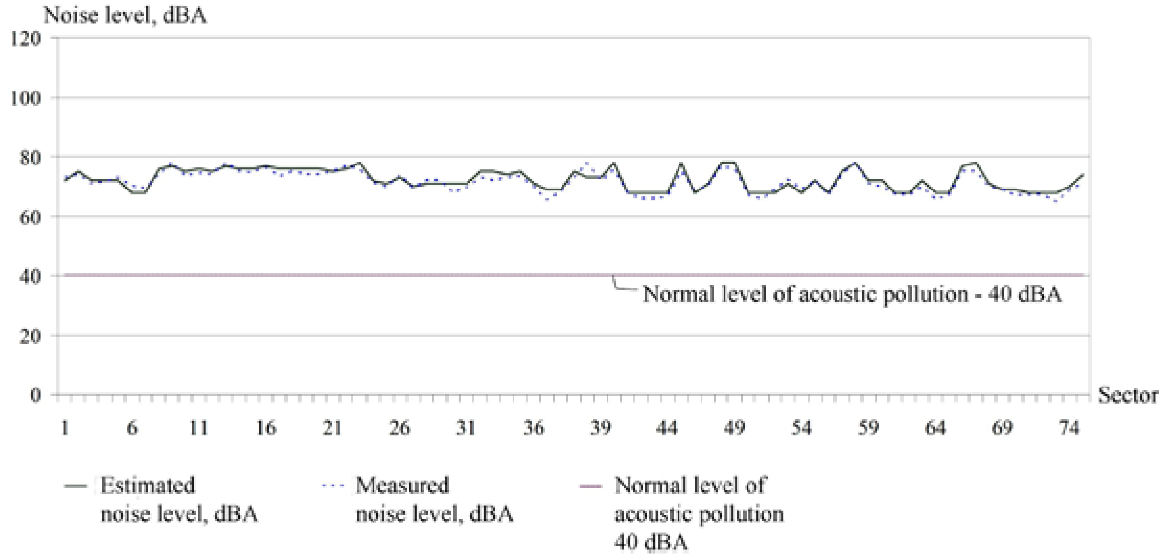

Figure 4a. Estimated and measured levels of noise pollution in sectors 1–75

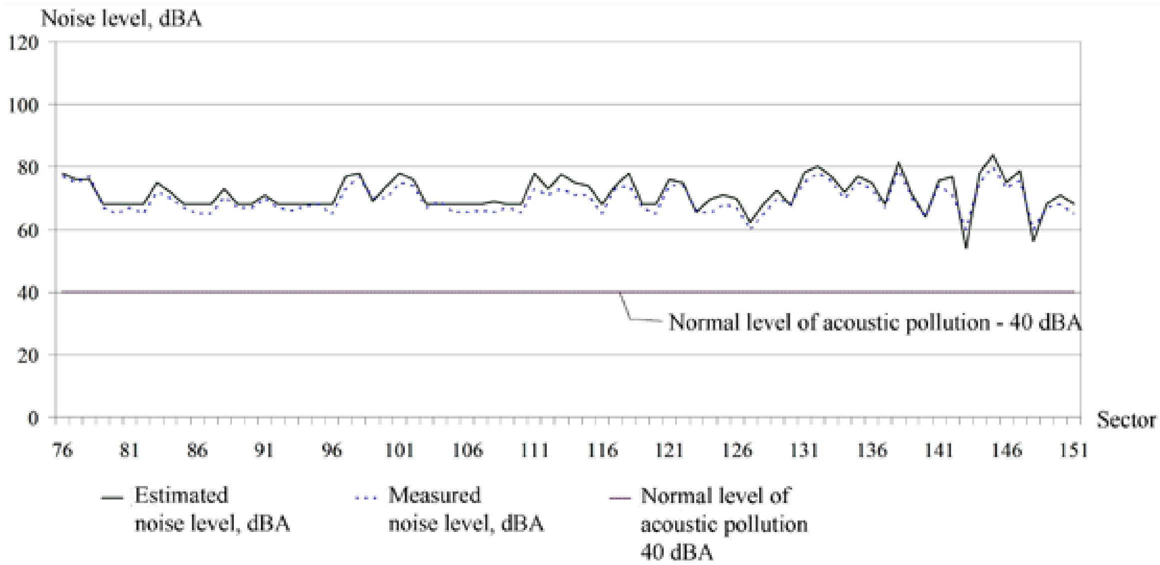

Figure 4b. Estimated and measured levels of noise pollution in sectors 76–151

to class V – "too noisy roads" and 3 road sections belong to class VI – "extremely noisy roads" (Fig. 5).

The State Sanitary Rules for Planning and Development of Settlements in Ukraine establish permissible sound levels in residential areas (sources with variable acoustic characteristics (vehicles, etc.) are characterized by equivalent and maximum sound levels (Table 2).

It should be noted that the noise level is high, approximately 75–80 dB(A), in certain sections of streets and directly in the area of intersections. Sections 98, 113, 131–133, 138, 144, 145, 147 have the highest excess of sanitary standards, which is justified by the highest traffic intensity in these sections. The daytime threshold values are exceeded by 20–28.9 dB(A), which is not acceptable. For example, studies of the noise pollution problem of territories in France also show that the usual threshold values are exceeded, even after the implementation of certain technical measures. However, this excess is 2–6 dB(A) above nighttime limits (the French regulatory threshold is 65 dB(A) at night), and while the situation is less critical for daytime levels that are usually below or very close to the threshold level (daytime French standard 70 dB(A)). (Ribeiro et al., 2021). A similar situation

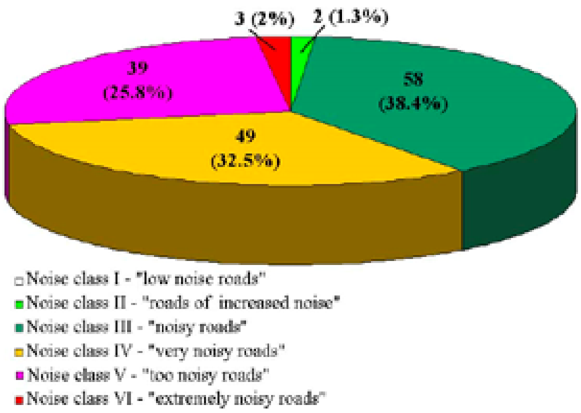

Figure 5. Noise classes of the studied road sections (roads belonging to class I "low noise roads" – 0%)

Table 2. Permissible sound levels on the residential development territory (http://epl.org.ua/human-posts/dopustymi-rivni-zvuku-shumu/)

Types of territories	Permissible sound levels (day), dB(A)	
	LAeq	LAmax
Territories directly adjacent to the buildings of hospitals, sanatoriums	45	60
Territories directly adjacent to residential buildings, buildings of polyclinics, outpatient clinics, rest homes, boarding houses, boarding houses, preschool institutions, schools and other educational institutions, libraries	55	70
Territories adjacent to the buildings of hotels and hostels	60	75

is observed in Brazil, where noise levels at all measured locations exceed the locally critical level of 55 dB(A), with noise-related annoyance reported by 48.4% of respondents (Paiva et al., 2019).

The main reasons for the noise load were the significant intensity of public and light freight transport, the large number of intersections and stops, as well as the lack of acoustic protection, including the lack of landscaping of the roadside. Exceeding the normative values of noise pollution extends to a distance of 50–150 m from the studied roads sections.

4.2. Influence of traffic intensity and other factors on the noise level

To establish the noise level from the traffic flow by calculation, were taken into account:

– vehicles types of the traffic flow;

– intensity and speed of movement;

– type of road construction;

– condition of the road surface.

Taking into account the results of the measurements and the peculiarities of the applied method for calculating the noise load, it was noted that the traffic intensity has the greatest influence on the noise level. In this regard, we will determine the degree of influence of other factors, based on the results obtained (Appendix A, Table A.1, A.2) and using the determination coefficient, since it demonstrates the density of the relationship between two or more indicators, as well as the adequacy of the regression model.

Using the obtained values of the measured and calculated levels of road noise, dependencies were built (Figs 6–13).

The determination coefficient for this dependence graph of the measured traffic intensity noise level in sections No.

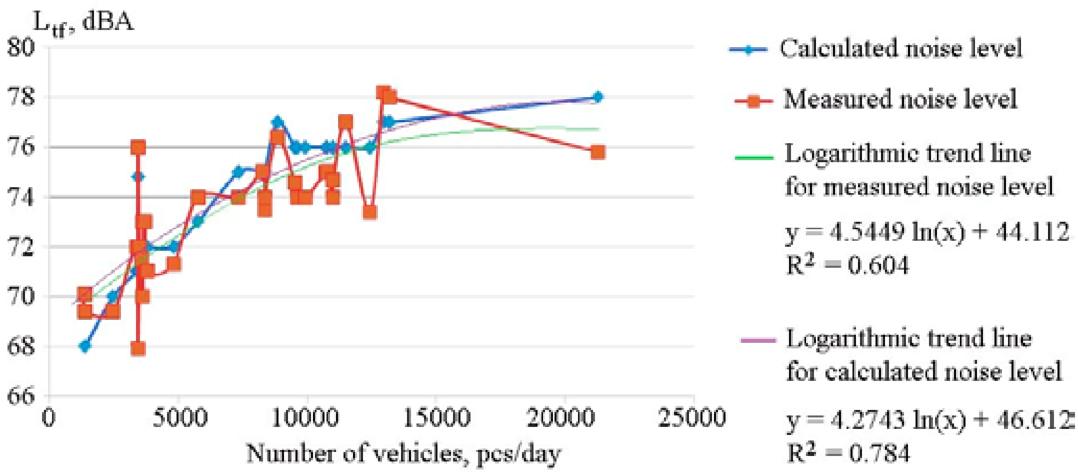

Figure 6. Graph of the dependence of the nose level on the daily intensity of traffic in sections No. 1–30 in the Shevchenko district of Poltava

1–30 is 0.604, which means the number of passing vehicles affects the noise level by 60.4%. While 39.6% is the influence of other factors that increase or muffle the noise level created by vehicles. This is also seen from Figure 6, where the deviation of this graph, depending on the simulated logarithmic trend line, in some places reaches 3.7 dB(A).

As can be seen from the purple graph, the calculated noise level determined according to the SAHU method (M 02071168–416:2016) depends on the traffic intensity by 78.4%, since the coefficient of determination for this function is 0.784. The deviation of this graph from the trend line does not exceed 1.9 dBA. This also suggests that 21.6% in this case was influenced by other factors such as the number of trucks and buses, traffic speed, type of surface, type of road intersection and development in the road area.

The determination coefficient for this schedule in sections No. 31–60 is 0.542, which means that the number of passing vehicles affects the noise level by 54.2%. While 45.8% is the influence of other factors that increase or muffle the noise level created by vehicles. This is also seen from Figure 7, where the deviation of this graph depending on the simulated logarithmic trend line in some places reaches 4.5 dB(A).

As can be seen from the purple graph, the calculated noise level determined according to the SAHU method (M 02071168–416:2016) is 70.1% dependent on traffic intensity, since the coefficient of determination for this function is 0.701. The deviation of this graph from the trend line does not exceed 1.8 dB(A). It also shows that 29.9% in this case, the noise level was influenced by other factors such as the number of trucks and buses, speed, type of surface, type of road intersection and development in the road area.

The determination coefficient for this schedule in sections No. 61–77 is 0.574, which means that the number

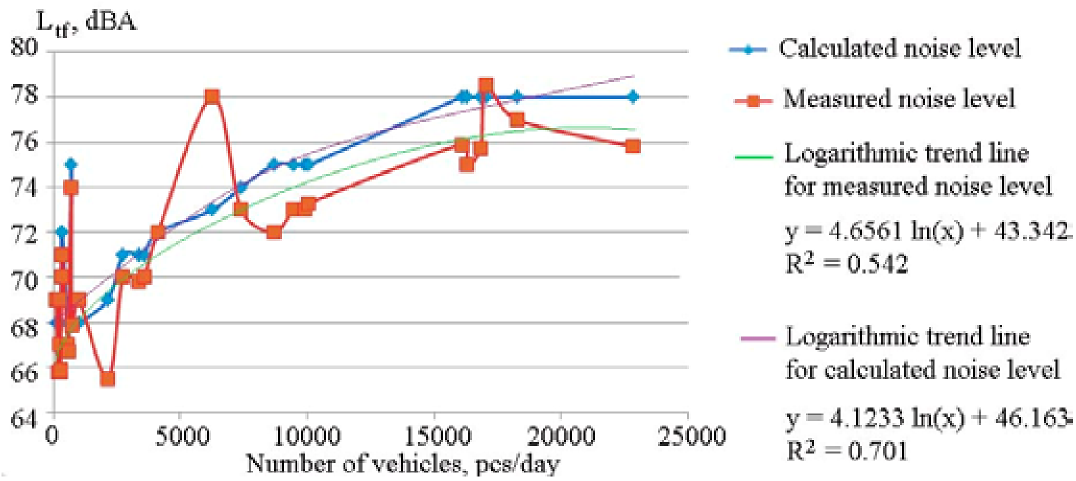

Figure 7. Graph of the dependence of the nose level on the daily intensity of traffic in sections No. 31–60 in the Shevchenko district of Poltava

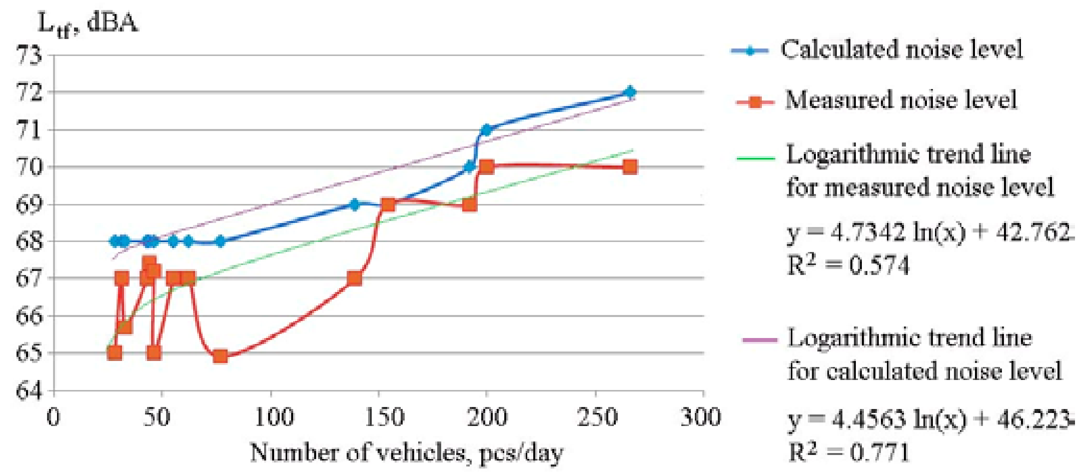

Figure 8. Graph of the dependence of the nose level on the daily intensity of traffic in sections No. 61–77 in the Shevchenko district of Poltava

of passing vehicles affects the noise level by 57.4%. While 42.6% is the influence of other factors that increase or muffle the noise level created by vehicles. This is also seen from Figure 8, where the deviation of this graph, depending on the simulated logarithmic trend line, is 2 dB(A) in some places.

As can be seen from the graph in purple, the calculated noise level determined according to the SAHU method (M 02071168–416:2016) is 77.1% dependent on traffic intensity, since the coefficient of determination for this function is 0.771. The deviation of this graph from the trend line does not exceed 0.5 dB(A). It also shows that 22.9% in this case, the noise level was influenced by other factors such as the number of trucks and buses, traffic speed, type of surface, type of road intersection and development in the road area.

The determination coefficient for this graph of the dependence of the measured noise level on the traffic intensity in sections No. 78–90 is 0.645, which means the number of passing vehicles affects the noise level by 64.5%. While 35.5% is the influence of other factors that increase or muffle the noise level created by vehicles. This can also be seen from Figure 9, where the deviation of this graph depending on the simulated logarithmic trend line in some places is 4.1 dB(A).

As can be seen from the graph in purple, the calculated noise level determined according to the SAHU method (M 02071168–416:2016) is 84.2% dependent on traffic intensity, since the coefficient of determination for this function is 0.842. The deviation of this graph from the trend line does not exceed 2 dB(A). It also shows that 15.8% in this case, the noise level was influenced by other factors such as the number of trucks and buses, traffic speed, type of surface, type of road intersection and development in the road area.

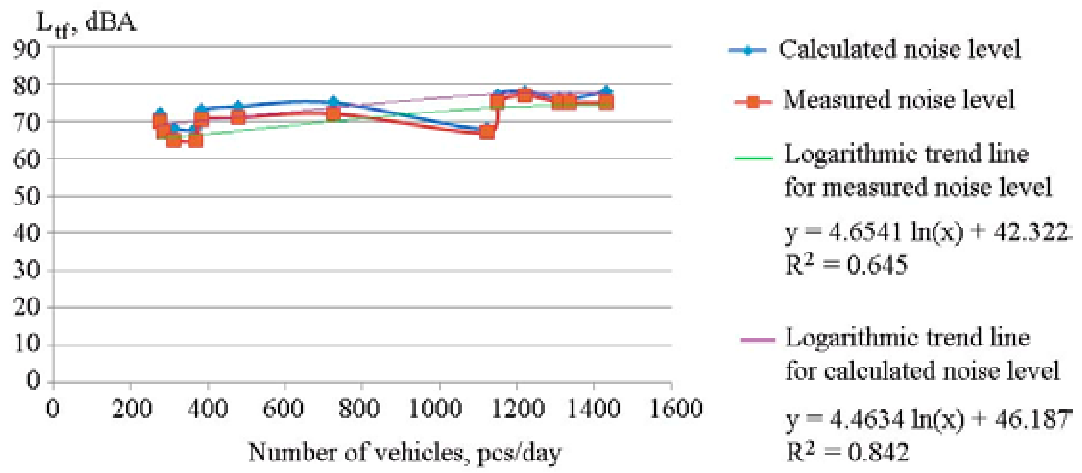

Figure 9. Graph of the dependence of the nose level on the daily intensity of traffic in sections No. 78–90 in the Shevchenko district of Poltava

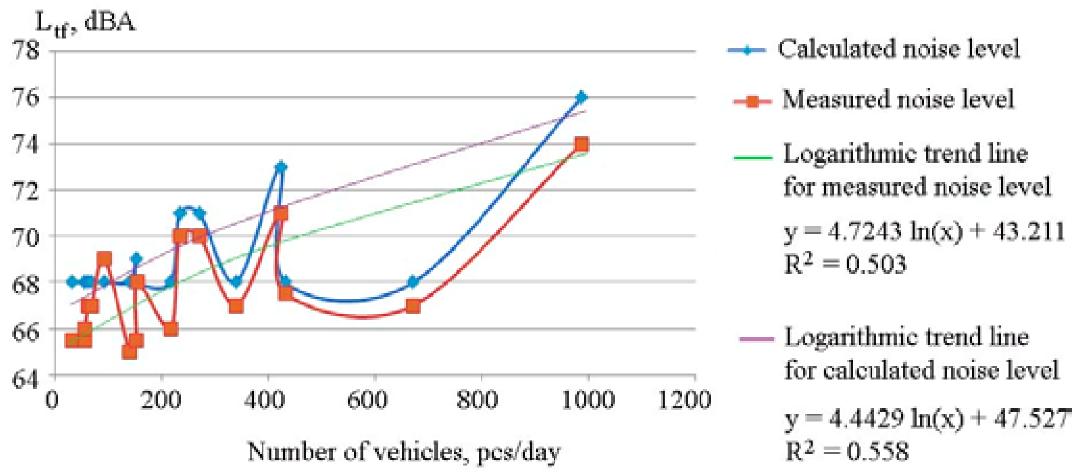

Figure 10. Graph of the dependence of the nose level on the daily intensity of traffic in sections No. 92–96, 102–110, 112, 119 in the Shevchenko district of Poltava

The determination coefficient for this graph of the dependence of the measured noise level on the traffic intensity in sections No. 91–96, 102–110, 112, 119 is 0.503, which means that the number of passing vehicles affects the noise level by 50.3%. While 49.7% is the influence of other factors that increase or muffle the noise level created by vehicles. This can also be seen from Figure 10, where the deviation of this graph, depending on the simulated logarithmic trend line, in some places is 2 dB(A).

As can be seen from the graph in purple, the calculated noise level determined according to the SAHU method (M 02071168–416:2016) is 55.8% dependent on traffic intensity, since the coefficient of determination for this function is 0.558. The deviation of this graph from the trend line does not exceed 2 dB(A). It also shows that 44.2% in this case, the noise level was influenced by other factors such as the number of trucks and buses, speed, type of surface, type of road intersection and development in the road area.

The determination coefficient for this graph of the dependence of the measured noise level on the traffic intensity in sections No. 97–101, 111, 113–118, 120–122 is 0.752, which means that the number of passing vehicles affects the noise level by 75.2%. While 24.8% is the influence of other factors that increase or muffle the noise level created by vehicles. This can also be seen from Figure 11, where the deviation of this graph depending on the simulated logarithmic trend line in some places is 2 dB(A).

As can be seen from the graph in purple, the calculated noise level determined according to the SAHU method (M 02071168–416:2016) is 78.8% dependent on traffic intensity, since the coefficient of determination for this function is 0.788. The deviation of this graph from the trend line does

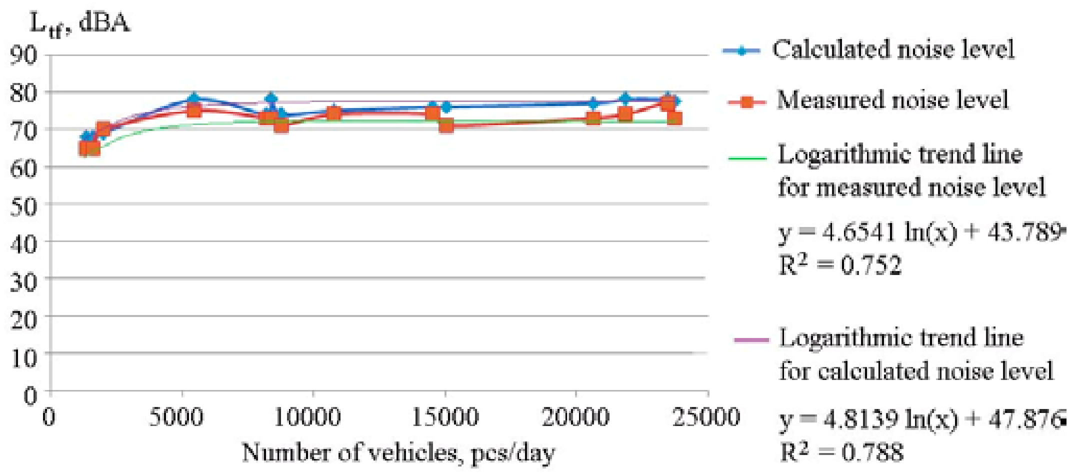

Figure 11. Graph of the dependence of the nose level on the daily intensity of traffic in sections No. 97–101, 111, 113–118, 120–122 in the Shevchenko district of Poltava

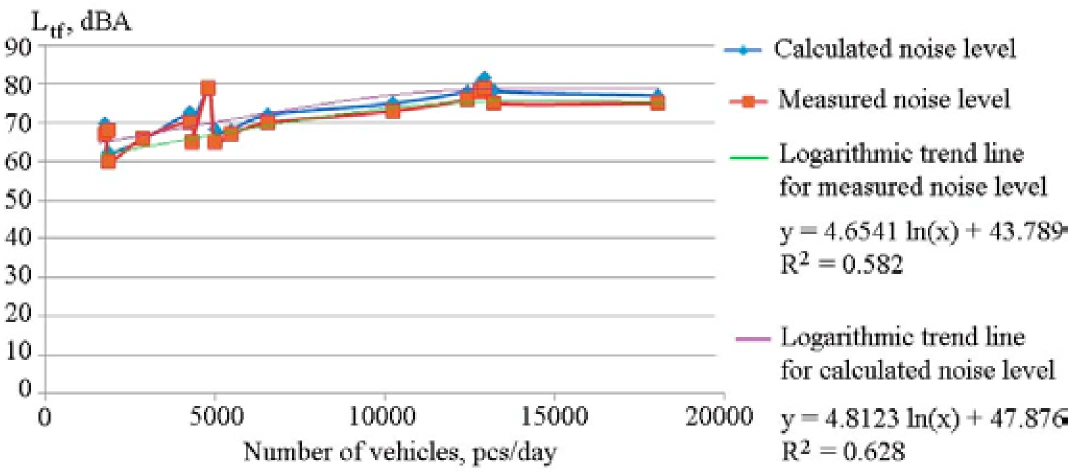

Figure 12. Graph of the dependence of the nose level on the daily intensity of traffic in sections No. 123–138 in the Shevchenko district of Poltava

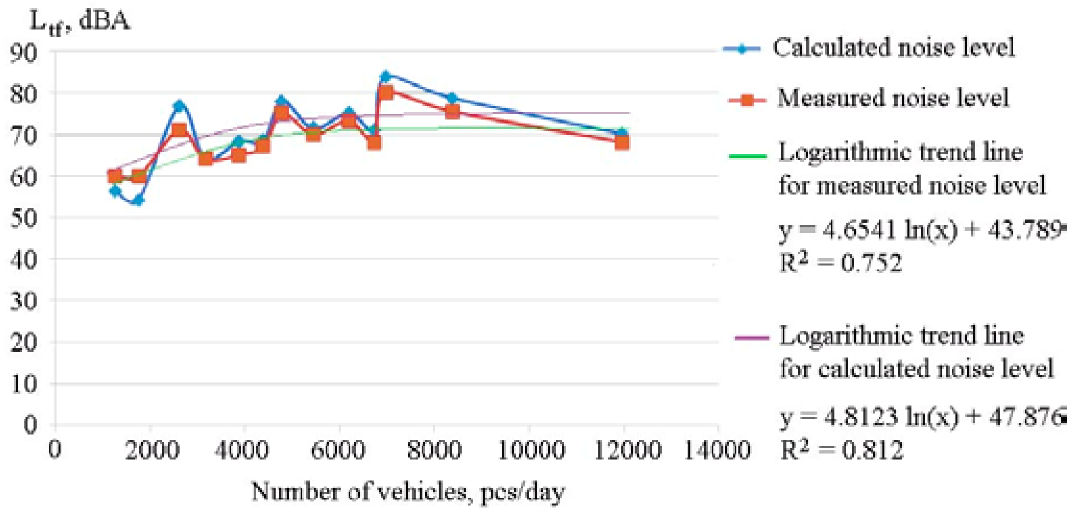

Figure 13. Graph of the dependence of the nose level on the daily intensity of traffic in sections No. 139–151 in the Shevchenko district of Poltava

not exceed 2 dB(A). It also shows that 21.2% in this case, the noise level was influenced by other factors such as the number of trucks and buses, traffic speed, type of surface, type of road intersection and development in the road area.

The determination coefficient for this plot of the measured noise level versus traffic intensity on sections No. 123–138 is 0.582, which means that the number of passing vehicles affects the noise level by 58.2%. While 41.8% is the influence of other factors that increase or muffle the noise level created by vehicles. This can also be seen from Figure 12, where the deviation of this graph depending on the simulated logarithmic trend line in some places is 8 dB(A).

As can be seen from the graph in purple, the calculated noise level determined according to the SAHU method (M 02071168–416:2016) is 62.8% dependent on traffic intensity, since the coefficient of determination for this function is 0.628. The deviation of this graph from the trend line does not exceed 5.7 dB(A). It also shows that 37.2% of noise in this case was influenced by other factors such as the number of trucks and buses, traffic speed, type of surface, type of road intersection and development in the road area.

The determination coefficient for this graph of the measured noise level versus traffic intensity in sections No. 139–151 is 0.752, which means the number of passing vehicles affects the noise level by 75.2%. While 24.8% is the influence of other factors that increase or muffle the noise level created by vehicles. This can also be seen from Figure 13, where the deviation of this graph depending on the simulated logarithmic trend line in some places is 6.9 dB(A).

As can be seen from the graph in purple, the calculated noise level determined according to the SAHU method (M 02071168–416:2016) is 81.2% dependent on traffic intensity, since the coefficient of determination for this function is 0.812. The deviation of this graph from the trend line does not exceed 5.2 dB(A). It also shows that 18.8% in this case, the noise level was influenced by other factors such as the number of trucks and buses, traffic speed, type of surface, type of road intersection and development in the road area.

The calculated results (Fig. 14) demonstrate a more significant influence of the traffic intensity of 55.8…84.2% compared to the influence of other factors of 15.8…44.2%, however, the results of the measured noise level showed that the traffic intensity affects the noise level not much more than other factors, which is 50.3…75.2% (compared to 24.8…49.7%) (Fig. 15). Based on the results, we see that the deviation of the graphs from the trend line for the calculated noise ranges from 1.9…5.7 dB(A), and for the measured noise this deviation is greater (2…6.9 dB(A)), therefore the calculated level of acoustic load more accurately reflects the actual noise level in the study area.

A more detailed analysis shows that high sound levels during measurements were found in sites 9 – Ivana Mazepy (1–32); 13–23 Veresnya (8–23); 22, 39 – Heroes of the anti-terrorist operation (71–83), Heroes of the anti-terrorist operation (2A–46a); 48 – Yevropeyska (108–124); 58 – Kharkivske Road (4/15–8); 66 – Oresta Levytskoho (2a–40); 76, 78 – Kahamlyka (2/43–53), Kahamlyka (33–35a); 98 – Heroyiv Chornobyltsiv (30a)–Sinna (47); 132 – Nebesnoyi Sotni (3–32); 136 – Shevchenka (31–54); 138 – Sobornosti (39–43); 145 – Volodymyra Kozaka (2–18).

The reason for the increase in noise in sections 9, 13, 22, 39, 66 could be the presence of bumps on the road, which were not taken into account by the correction factors in the calculation. It was determined that the type of pavement in these areas was asphalt concrete, however, the presence of

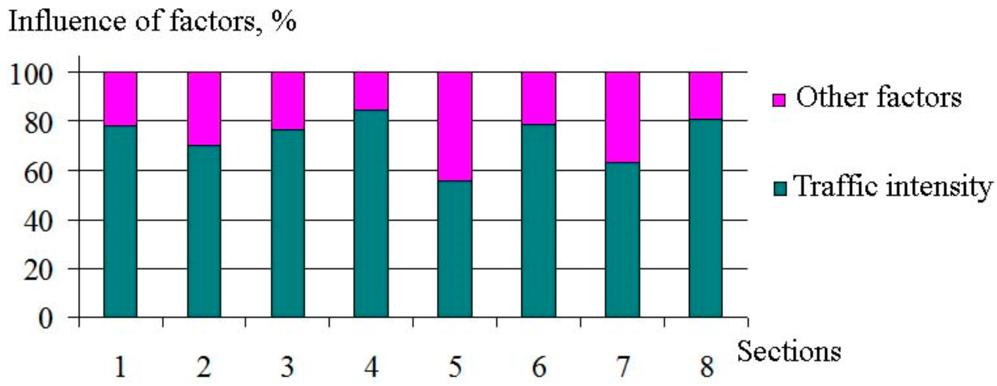

Figure 14. Calculated results of the traffic intensity influence on the noise level

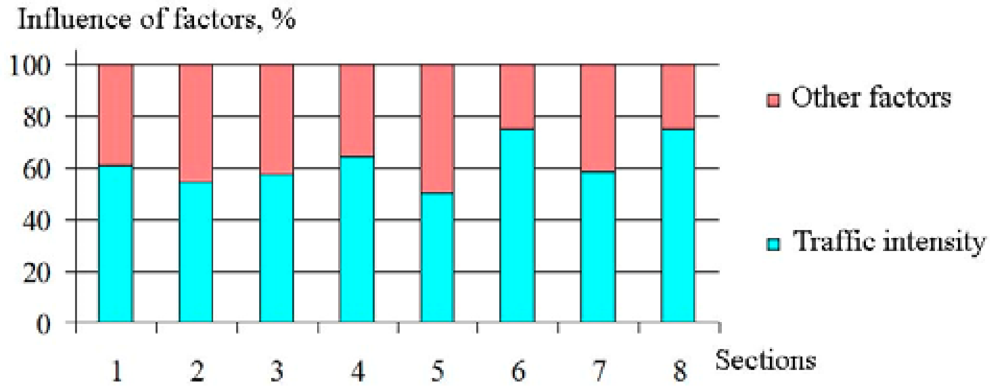

Figure 15. Measured results of the traffic intensity influence on the noise level

hatches and bumps on the road in some places served as an additional sound disk during the movement. Since this factor, which increased the noise level by 2–3.5 dBA, was not provided for in the methodology, this should be taken into account when making further adjustments to the calculation methodology.

An increase in the sound level in section 58 provoked a significant number of cars, since this section of the section is located on the Kyiv-Kharkov highway, where a large number of various vehicles pass over a period of time.

Section 48, 136, 138 is one of the main roads of the city, it has a large number of stops and junctions of different streets, so there is a significant excess of permissible noise levels here.

The increase in sound levels in section 132 provoked public transport. When calculating, it is necessary to take into account the correction for the number of stops of public transport, which affects the increase in sound level, since slowing down vehicles stop and start moving, increasing speed – has a greater noise impact than vehicles moving at a constant speed.

One of the noise increase factors in sections 76, 78, 145 is the movement of vehicles at a non-constant speed. In addition, the reason for the discrepancies between the calculated and natural noise levels could be additional noise from neighbouring sections of the road.

In section 98 has a lower noise level. The reason for the decrease in the noise level could be the slowdown in traffic, since the road section has a significant number of exits and pedestrian crossings. In addition, the roadside area is characterized by the presence of a green area, which dampens sound vibrations from vehicles.

4.3. Public risk and noise reduction measures

The obtained results make it possible to assess the risk to public health from the noise of motor vehicles, namely, the number of people living in certain noise conditions was determined (Fig. 16).

According to City Hall, it has been established that 62,550 people live in areas where the noise level exceeds the permissible value for the area near residential buildings. At risk are children, retirees and unemployed youth, who are often on the streets, exposed to the threatening effects of acoustic pollution. The main causes of noise pollution are the significant intensity of public and light freight transport,

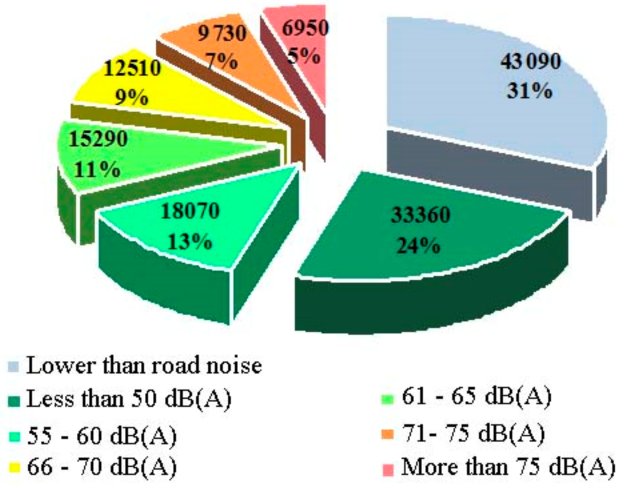

Figure 16. Diagram of the distribution of the population that lives in a certain zone of noise pollution

the large number of intersections and stops, as well as the lack of acoustic protection, including the lack of landscaping of the roadside.

Other researchers also note that congestion and lack of free traffic, combined with unorganized traffic and illegal parking along roads, lead to severe noise pollution in these areas (Banerjee et al., 2008; Singh et al., 2017).

It is clear that noise pollution is widespread and has long-term health effects (Singh et al., 2018). Lack of knowledge about the adverse effects of road noise on human health results in a lack of noise control. Given that this is a serious health hazard resulting in human suffering, noise pollution issues cannot be ignored. For the sake of the well-being of the population and future generations, it is essential to apply appropriate measures to reduce noise and to control noise pollution.

Landscaping is an effective means of combating noise in cities. Trees planted closely, surrounded by thick bushes, significantly reduce man-made noise and improve the urban environment (Yofianti & Usman, 2021; Ivanisova et al., 2021). Maple, poplar, linden absorb from 10 to 20 dB of sound signals, shrubs can reduce the noise load by 25 dB (Ivanisova et al., 2021). For this, several strips are formed with gaps between them equal to the height of the trees. The width of the strip should be at least 5 m, and the height of the trees should be at least 5–8 m. On the noise protection strips, the crowns of the trees should be tightly closed to each other. A dense shrub is planted under the crowns in a checkerboard pattern. Coniferous green spaces are more effective for noise protection (Pawłat-Zawrzykraj et al., 2021), the noise protection properties of which do not depend on the season. However, in the conditions of the city, they grow poorly, and therefore it is more expedient to combine them with deciduous trees.

4.4. Legal mechanisms for road noise control

Concrete steps need to be taken to combat noise pollution, such as educating the public about adverse health hazards, enacting laws to regulate noise levels. Legal mechanisms must be effective and work in the interests of the urban population, since it is the urban population that is more able to work, which ensures the economic stability of the country. A similar opinion about the importance of reviewing and updating public policy on environmental noise is shared by the authors of a study in Brazil (Paiva et al., 2019).

In 1999, Ukraine ratified the Aarhut Convention, which states that: "Environmental information goes beyond the elements of the environment and their interaction and includes information about anthropogenic and non-anthropogenic factors and activities or measures that have or may have an impact on the elements of the environment. In addition, this definition also includes the economic analyzes and assumptions used in making decisions on environmental matters". The Convention clearly identifies the components of environmental information: factors such as substances, energy, noise and radiation, and activities or measures, including administrative measures, environmental agreements, policies, legislation, plans and programs that affect or may affect the components of the environment. Article 50 of the Constitution of Ukraine provides that everyone has the right to a safe environment for life and health and to compensation for damage caused by violation of this right. Everyone is guaranteed the right of free access to information about the state of the environment, the quality of food products and household items, as well as the right to disseminate it. Such information cannot be classified. According to the Law of Ukraine "On National Safety" (Document 2469-VIII), the system of public authorities, local governments is designed to protect national security, supported by ensuring environmental security. In accordance with this document, all people have the right to freely seek, receive, and disseminate environmental information. This provision is equally available to citizens, stateless persons, foreigners. Unfortunately, in Ukraine these norms are partially implemented, as there are organizations that provide monitoring of water quality, the state of atmospheric air, the amount of solid household waste; there are special mechanisms for free access to this information. However, these positions are not respected with regard to information on noise pollution or any type of radiation, which is a violation of the relevant regulation.

Another problem is that currently Ukrainian environmental legislation is mainly based on Soviet standards, measurement methods and permissible noise levels. Despite the fact that many normative documents date back to the recent year of publication, they almost completely repeat the content of the predecessor standards, without revising and taking into account the modern standard of living and the latest achievements of science. It was found that some norms, such as measurements of noise pollution levels in residential areas, were approved in the Soviet era and have not been revised since the last century. The urgent problem of noise pollution in the cities of Ukraine requires more stringent requirements for compliance with noise pollution levels (Reshetchenko et al., 2019).

In addition to the above, codes, laws and by-laws in Ukraine provide for legal regulation of issues related to violation of environmental protection legislation, which is (http://nbuv.gov.ua/UJRN/Unir_2013_25_21):

– |in determining the amount of damage caused to the environment, according to special methods;
– in establishing the procedure for compensation for damage caused to the environment.

Thus, the Code of Ukraine about Administrative Offences (CUAO) defines responsibility for violation of the requirements of legislative and other regulatory legal acts to protect the population from the harmful effects of noise or the rules for maintaining silence in settlements and public places. In particular, Article 182 of CUAO provides for punishment in the form of a warning or imposition of a fine on citizens from 5 to 15 non-taxable minimum incomes of citizens and the imposition of a fine on officials and citizens – business entities – from fifteen to thirty non-taxable minimum incomes of citizens (https://zakon.rada.gov.ua/laws/show/80731–10#Text). In case of a repeated similar offense during the year, a fine of fifteen to thirty thousand rubbles is provided for citizens with confiscation of sound-reproducing equipment, pyrotechnics, and other objects of silence (https://zakon.rada.gov.ua/laws/show/80731–10 #Text). That is, if we translate these fines into a monetary equivalent, then it turns out that they are so negligible, small that you can continue to violate the law without thinking about the consequences. But at the same time, it is difficult to apply this to vehicles of any form of ownership, which quite legally has the ability to move along any city roads while observing road signs.

At the same time, in accordance with the Law of Ukraine "On Local Self-Government" and Article 24 of the Law of Ukraine "On Ensuring the Sanitary and Epidemiological Welfare of the Population", executive authorities, local governments, enterprises, institutions, organizations and citizens, when carrying out any type of activity, are obliged take a number of actions aimed at preventing and reducing the harmful effects on public health of noise, non-ionizing radiation and other physical factors. Consequently, for the lack of landscaping of the roadside zone and the irrationally organized movement of vehicles, including passenger transport of any form of ownership and trucks, local governments should be held responsible. However, this is unfortunately not the case. In addition, the Law of Ukraine "On the Basic Principles (Strategy) of the State Environmental Policy of Ukraine for the period up to 2020" (https://zakon.rada.gov.ua/laws/show/2818-17#Text) in Section 3 "Strategic goals and task" includes such tasks as:

– to equip settlements located near highways with a population of at least 500 thousand people by 2015 and with a population of at least 250 thousand people by 2020 to be equipped with anti-noise structures/screens;
– to improve the regional environmental policy, namely, to reduce the negative impact of urbanization processes on the environment, to increase the indicators of landscaping and public green areas, to reduce by 2020 the level of air pollution, water pollution, noise and electromagnetic pollution.

Section 4 "Instruments for the implementation of the national environmental policy" of the same law (https://zakon.rada.gov.ua/laws/show/2818–17#Text) states: "The implementation of environmental policy requires the effective functioning of the system of legislation in the field of environment, aimed at achieving national priorities. The main requirements for such legislation are its compliance with the Constitution of Ukraine, the approximation of the relevant EU directives, …"

However, already the Law of Ukraine "On the Basic Principles (Strategy) of the State Environmental Policy of Ukraine for the period up to 2030" (https://zakon.rada.gov.ua/laws/show/2697–19#Text) ignored the issues of noise pollution , although this environmental problem is becoming increasingly important.

The problem of Ukrainian environmental law lies in the total violation of environmental human rights and the lack of guarantees for their restoration, the imperfect procedure for bringing those responsible for violating the norms in the field of environmental protection to legal responsibility (Babič, 2019). Unfortunately, a large number of appeals from citizens of Ukraine to the European Court of Human Rights (ECHR) indicates a systematic violation of their rights to a safe environment for life and health. Unfortunately, no provisions of the Convention on Human Rights guarantee the right to protect the natural ecological environment. The ECHR can only recognize a violation of environmental human rights in the context of Article 8 of the Convention, which guarantees the right to respect for one's private life (Babič, 2019).

As a result, the situation is such that the modern legal mechanism in Ukraine is not sufficiently developed to cope with such an environmental problem as noise pollution from vehicles and needs to be seriously improved.

5. Conclusions

Noise pollution has unique properties, namely: its level can change in short time intervals and does not accumulate in the body. However, persistent noise has a significant impact on health.

The calculation method used turned out to be more accurate than the measured results and showed a significant effect of traffic intensity on noise pollution. Apparently, the low measurement accuracy is justified by outdated road noise measurement standards, which, in turn, need to be seriously revised. However, the calculations did not take into account some factors, such as the presence of trucks and buses, speed, type of surface, type of road intersection and buildings in the area of the road, which must be added in the improved version.

Among the factors that also contribute to an increased noise load in the study areas are the movement of passenger and light freight vehicles, the lack of free traffic combined with a large number of intersections, stops and illegal parking along the roads, as well as the lack of acoustic protection, including roadside landscaping. . Ensuring landscaping of roadside areas in residential areas of the city adjacent to highways is necessary, because due to dense development along the roads a large number of residential buildings, public premises, office buildings are concentrated.

In addition, reducing noise levels by optimizing traffic flows is one of the priority areas and it is in this area that it is necessary to ensure the compliance of the environmental legislation of Ukraine with the provisions of the acquis communautaire sources.

It is important to improve the Law of Ukraine "On the Basic Principles (Strategy) of the State Environmental Policy of Ukraine for the period up to 2030" in terms of noise pollution as a serious environmental factor affecting people's health.

Ukrainian legislation still needs to undergo many changes to reach a level where it can be used as a control lever to achieve a safe ecological environment. A significant increase in fines for violation of noise legislation and the implementation of the provisions of Directive 2002/49/EC of the European Parliament and of the Council of June 25, 2002 on the assessment and management of processes related to noise pollution are necessary. The purpose of this is to create noise maps of large cities, which would allow traffic noise to be predicted, and as a result to more effectively develop and implement measures to reduce noise pollution.

Taking into account international experience, it is important for Ukraine to implement the conclusions of the ECHR into national legislation in order to guarantee the observance, protection and restoration of the fundamental rights of citizens in the field of ecology.

Acknowledgements

This study was carried out in accordance with the plans of scientific work of the Department of Applied Ecology and Environmental Sciences, National University "Yuri Kondratyuk Poltava Polytechnic", Poltava, Ukraine. The authors are deeply grateful to the university administration for providing the opportunity for scientific research.

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Annex A

Table A.1. Characteristics of traffic flows in Shevchenkivskyi district of Poltava

No. the investigated section of the highway	Name of the street (and number of buildings) on which the section of the highway falls	Hourly traffic intensity by vehicleson types on road section, pcs/hour				Coefficient of reduction of hourly intensity to daily, K_{red}	Daily intensity of movement, pcs/day, I_d	Estimated sound level from the traffic flow, dB(A), L_{tf}^{calc}
		Total, N_{hour}	including					
			cars	trucks	buses			
1	2	3	4	5	6	7	8	9
1	M. Hrushevskoho(1–4)	318	288	30	0	11.7	3720.6	72
2	M. Hrushevskoho (4–22)	627	546	54	27	11.7	7335.9	75
3	Tsiolkovskoho (1–21)	325	256	45	24	11.7	3802.5	72
4	Tsiolkovskoho (21–37)	306	243	42	21	11.7	3580.2	72
5	Tsiolkovskoho (38–59)	311	249	43	19	11.7	3638.7	72
6	Almazna (1, 2, 3, 6)	117	114	3	0	11.7	1368.9	68
7	Almazna (5–18)	119	118	1	0	11.7	1392.3	68
8	Stepovoho Frontu (2–24)	940	629	201	110	11.7	10998	76
8	Stepovoho Frontu (1–48)	629	420	202	7	11.7	7359.3	75
9	Ivana Mazepy (1–32)	1107	894	57	156	11.7	12951.9	77
10	Ivana Mazepy (13–37)	713	524	42	147	11.7	8342.1	75
11	Ivana Mazepy (37–59)	813	630	45	138	11.7	9512.1	76
12	23 Veresnya (1–7)	714	612	72	30	11.7	8353.8	75
13	23 Veresnya (8–23)	1128	897	66	165	11.7	13197.6	77
14	Kyyivske Road (4–38)	921	711	204	6	11.7	10775.7	76
15	Kyyivske Road (44–48)	941	725	211	5	11.7	11009.7	76
15	Shevchenka (22–36)	337	290	43	4	11.1	3440.7	74.8
16	Kyyivske Road (50–60)	756	618	129	9	11.7	8845.2	77
17	Kyyivske Road (62–92)	1062	849	57	156	11.7	12425.4	76
18	Velykotyrnivska (1–10)	917	680	76	161	11.7	10728.9	76
19	Velykotyrnivska (10–22)	849	698	56	95	11.7	9933.3	76
20	Heroyiv Stalinhradu (9–17)	820	632	46	142	11.7	9594	76
21	Heroyiv Stalinhradu (1–9)	706	531	40	135	11.7	8260.2	75
22	Heroes of the anti-terrorist operation (71–83)	984	790	47	147	11.7	11512.8	76
23	Velykotyrnivska (34)–Heroyiv Stalinhradu (34/24)	1498	743	545	210	14.2	21272	78
24	Nikitchenka (2)–Marshal Konev Boulevard (9)	339	234	95	10	14.2	4814	72
25	Yury Pobedonostsev Boulevard (9–12)	256	198	45	13	14.2	3635	71
26	Heroes of the anti-terrorist operation (114K1–116)	405	237	156	12	14.2	5751	73
27	Heroes of the anti-terrorist operation (118/2к3–118/2к4)	174	123	32	19	14.2	2471	70
28	Ognivska (2a–14)	240	176	54	10	14.2	3408	71
29	Shchepotyev Boulevard (9–7a)	245	187	49	9	14.2	3479	71
30	Kolektyvna	242	198	37	7	14.2	3436	71
31	Stanislavskoho (2/14–6)	237	186	42	9	14.2	3365	71
32	Bayana (128–96)	690	437	234	19	13.7	9453	75
33	Arktichniy bystreet (12a–8)	633	398	212	23	13.7	8672	75
34	Arktichniy bystreet (14–24)	540	345	178	17	13.7	7398	74
35	Heroes of the anti-terrorist operation (94–76/14)	734	698	34	0	13.7	10056	75
36	Kolektyvnyy bystreet (1–11)	200	188	12	0	13.7	2740	71
37	Hrebinky (28–80a)	139	110	29	0	15.4	2141	69
37	Hrebinky (80a–94)	122	95	27	0	15.4	1879	69
37	Hrebinky (120–94)	117	98	19	0	13.7	1630	69

No. the investigated section of the highway	Name of the street (and number of buildings) on which the section of the highway falls	Hourly traffic intensity by vehicleson types on road section, pcs/hour				Coefficient of reduction of hourly intensity to daily, K_{red}	Daily intensity of movement, pcs/day, I_d	Estimated sound level from the traffic flow, dB(A), L_{tf}^{calc}
		Total, N_{hour}	including					
			cars	trucks	buses			
1	2	3	4	5	6	7	8	9
38	Bayana 1(a–39)	48	45	3	0	15.4	739	75
38	Bayana (39–53)	643	403	211	29	15.4	9902	75
38	Bayana (94–58)	566	378	178	10	13.7	7754	74
39	Heroes of the anti-terrorist operation (2a– 46a)	440	402	36	2	14.2	6248	73
39	Heroes of the anti-terrorist operation (74–46a)	450	287	156	7	13.7	6165	73
40	Rayisy Kyrychenko (66)–Yevropeyska (66)	1478	1045	371	62	15.4	22761	78
40	Yevropeyska (68–86)	1607	1018	517	72	14.2	22819	78
41	Lyali Ubyyvovk (3–18b)	51	45	6	0	14.2	724	68
42	Kropyvnytskoho bystreet (2a–22a)	20	16	4	0	14.2	284	68
43	Spil′chans′kyy bystreet (3–31)	19	15	4	0	14.2	270	68
44	Zalizna (3–15)	52	45	7	0	11.7	608	68
45	Yevropeyska (102–104)	1390	630	237	143	11.7	16263	78
46	Chaykovskoho bystreet (7)–Yevropeyska (141)	65	60	5	0	15.4	1001	68
47	Matrosova (27)–Yevropeyska (147)	232	187	45	0	15.4	3573	71
48	Yevropeyska (108–120)	1561	995	489	77	11.7	18264	78
48	Yevropeyska (122–124)	1479	956	454	69	11.7	17304	78
49	Yevropeyska (128–136)	1438	932	453	53	11.7	16825	78
49	Yevropeyska (138–144)	1375	912	398	65	11.7	16087	78
50	Stepovoho Frontu (5)–Mayakovskoho (38)	22	20	2	0	11.7	257	68
51	Kustarniy bystreet (3–9)	15	13	2	0	11.7	175	68
52	Tokarnyy bystreet (2–12)	21	18	3	0	11.7	246	68
54	Komunal′nyy bystreet (1–5a)	9	8	1	0	11.7	105	68
55	Avtobazivska (7)–Yevropeyska (173)	290	236	54	0	14.2	4118	72
56	Harazhna	39	34	5	0	14.2	554	68
57	Malorudchanska (1–23)	64	42	22	0	11.1	710	75
58	Kharkivske Road (4/15)	1018	843	166	9	13.7	13947	78
58	Kharkivske Road (8)	1244	1028	200	16	13.7	17043	78
59	Danyla Apostola (4–30)	31	27	4	0	11.1	344	72
60	Veterynarna (19a–25)	29	25	4	0	11.1	322	72
60	Veterynarna (34–37)	24	20	2	2	11.1	266	72
61	Motornyy bystreet (2–18)	4	4	0	0	11.1	44	68
62	Veterynarnyy bystreet (2–20)	5	5	0	0	11.1	55	68
63	Danyla Apostola (9a–27)	24	20	4	0	11.1	266	72
64	Zlahody (19–31)	3	3	0	0	11.1	33	68
65	Veterynarnyy bystreet (2a–20)	4	4	0	0	13.7	55	68
66	Oresta Levytskoho (2a–40)	84	74	10	0	13.7	1151	77
66	Oresta Levytskoho (6–40)	76	67	9	0	13.7	1041	77
67	Kharkivske Road (6–29)	1067	900	157	10	15.4	16432	78
68	Lobachevs′koho (3–15/48)	13	11	2	0	15.4	200	71
69	Zelena (31/33–71/1)	10	10	0	0	15.4	154	69
70	Hazova (9–19)	9	9	0	0	15.4	139	69
71	Rankova (6/6–40/5)	4	4	0	0	15.4	62	68
72	Vodyana (4–20)	3	3	0	0	15.4	46	68
73	Kyryla Os′maka	5	5	0	0	15.4	77	68
74	Serafymovycha (2/43–22/1)	14	14	0	0	13.7	192	70
75	Profspilkova (2/39–51)	35	33	2	0	13.7	479	74
76	Kahamlyka (2/43–53)	892	775	113	4	13.7	12220	78

No. the investigated section of the highway	Name of the street (and number of buildings) on which the section of the highway falls	Hourly traffic intensity by vehicleson types on road section, pcs/hour				Coefficient of reduction of hourly intensity to daily, K_{red}	Daily intensity of movement, pcs/day, I_d	Estimated sound level from the traffic flow, dB(A), L^{calc}_{tf}
		Total, N_{hour}	including					
			cars	trucks	buses			
1	2	3	4	5	6	7	8	9
77	Kahamlyka (35a–37a)	867	750	112	5	14.2	12311	76
77	Kahamlyka (76a–82)	840	730	104	6	14.2	11928	76
78	Kahamlyka (29–33)	818	678	123	8	15.4	12597	76
78	Kahamlyka (33–35a)	892	775	113	4	15.4	13737	76
79	Dovzhenka to turn	73	63	5	5	15.4	1124	68
80	Dovzhenka (3a–19)	26	19	5	2	14.2	369	68
80	Dovzhenka (55–79)	22	17	5	0	13.7	301	72
80	Dovzhenka (37–53)	20	15	5	0	13.7	274	72
80	Dovzhenka (3–35)	24	19	5	0	13.7	329	72
81	Honcharova	20	17	3	0	14.2	284	68
82	Sosyury (62–51)	22	17	5	0	14.2	312	68
83	Dovzhenka (70–62)	53	44	9	0	13.7	726	75
83	Sofiyi Kovalevskoyi (1–29)	35	30	5	0	14.2	497	74
83	Sofiyi Kovalevskoyi (29a–63)	13	12	1	0	14.2	185	70
84	Hlybokyy bystreet (1–16)	18	18	0	0	15.4	277	72
84	Hlybokyy bystreet (22–50)	15	15	0	0	15.4	231	71
84	Hlybokyy bystreet (54–72)	17	17	0	0	15.4	262	71
85	Levadna (24–44)	1	1	0	0	15.4	15	68
85	Levadna (3–23/13)	2	2	0	0	15.4	31	68
86	Parnykovyy bystreet	2	2	0	0	14.2	28	68
87	Dobrolyubova (22–40)	3	3	0	0	15.4	46	68
88	Verkhniy bystreet (22/1–28)	27	21	6	0	14.2	383	73
88	Verkhniy bystreet (3–17)	23	17	6	0	14.2	327	72
89	Karpenka-Karoho bystreet (20–30)	3	3	0	0	14.2	43	68
90	Tobilevycha (52–71)	3	3	0	0	14.2	43	68
91	Tobilevycha (3–25/5)	19	18	1	0	14.2	270	71
91	Tobilevycha (24/8–47)	10	10	0	0	14.2	140	69
92	Lesi Ukrayinky (3–23)	22	19	3	0	15.4	339	68
93	Oleny Pchilky (19–3)	14	12	2	0	15.4	216	68
94	Panasa Myrnoho (3–41)	28	25	3	0	15.4	431	68
94	Panasa Myrnoho (40–54)	9	8	1	0	14.2	128	69
95	Mykhailivsky Yar (25–3)	10	9	1	0	15.4	154	68
96	Herashchenka (30–3b)	9	8	1	0	15.4	139	68
97	Rayisy Kyrychenko (66)–Kahamlyka	1341	661	540	140	15.4	20651	77
97	Kahamlyka (3–29)	527	430	87	10	15.4	8116	74
98	Heroyiv Chornobyltsiv (30a)–Sinna (47)	1524	982	441	101	15.4	23470	78
98	Rayisy Kyrychenko (72–66)	1422	859	451	112	15.4	21899	78
99	Ostapa Vyshni (14a–5)	129	81	46	2	15.4	1987	69
100	Patriarkha Mstyslava (4–31)	648	368	74	6	13.7	6137.6	73.8
101	Patriarkha Mstyslava (68–70)	398	374	22	2	13.7	5453	78
101	Patriarkha Mstyslava (72–134)	470	436	32	2	13.7	6439	78
101	Patriarkha Mstyslava (1–79)	368	312	50	6	13.7	5041.6	71.2
102	Dovzhenka (107–115)	72	62	10	0	13.7	986	76
102	Dovzhenka (70–103)	68	58	10	0	13.7	932	76
103	Hertsena (1–15/17)	4	4	0	0	15.4	62	68
104	Dobrolyubova (48/80–80)	6	6	0	0	15.4	92	68
105	Hryboyedova (3–35)	2	2	0	0	15.4	31	68

No. the investigated section of the highway	Name of the street (and number of buildings) on which the section of the highway falls	Hourly traffic intensity by vehicleson types on road section, pcs/hour				Coefficient of reduction of hourly intensity to daily, K_{red}	Daily intensity of movement, pcs/day, I_d	Estimated sound level from the traffic flow, dB(A), L^{calc}_{tf}
		Total, N_{hour}	including					
			cars	trucks	buses			
1	2	3	4	5	6	7	8	9
106	Vesnyanyy bystreet	4	4	0	0	13.7	55	68
107	Chovnovyy bystreet (3–11/6)	5	5	0	0	11.1	55	68
108	Dzherelnyy bystreet (7–15)	11	10	1	0	13.7	151	69
108	2-y Trubnyy bystreet (3–9)	10	10	0	0	13.7	138	69
109	Chovnovyy bystreet (31–31b)	5	4	1	0	13.7	68	68
110	Chovnovyy bystreet (23–27)	9	9	0	0	11.1	100	68
110	Chovnovyy bystreet (24–30)	21	17	3	0	11.1	233	71
111	Pivdenna (1a–7)	285	261	22	2	11.1	3163	78
111	Pivdenna (11–75)	755	697	54	4	11.1	8380	78
112	Pivdenna (77–159)	38	26	12	0	11.1	422	73
113	Yevropeyska	1542	1212	330	78	15.4	23746.8	77.6
114	Heroyiv Chornobyltsiv (30a–30)	600	239	361	0	13.7	8220	75
114	Chapayeva (28)–Rayisy Kyrychenko (52)	260	213	47	0	13.7	3562	71
114	Heroyiv Chornobyltsiv (19)–Novyy bazar (22)	977	765	212	0	15.4	15046	76
114	Heroyiv Chornobyltsiv (9b–5)	721	562	150	9	15.4	11103	75
114	Heroyiv Chornobyltsiv (5–2)	687	552	132	3	15.4	10580	75
115	Vyacheslava Chornovola (25/7–43)	569	459	110	0	15.4	8763	74
116	Heroyiv Chornobyltsiv (19)–Rayisy Kyrychenko (67)	103	81	22	0	15.4	1586	68
117	Olesya Honchara (1b–15)	533	321	212	0	15.4	8208	74
118	Sinna (29)–Shevchenka (63a)	1597	1001	469	127	13.7	21879	78
118	Sinna (29–31/32)	1565	1179	337	49	13.7	21440	78
119	Heroyiv Chornobyltsiv (30)–Tupyy bystreet (2)	49	37	12	0	13.7	671	68
120	Rayisy Kyrychenko (43)–Shevchenka (43)	97	78	19	0	13.7	1329	68
121	Novyy bazar (22–4)	943	765	178	0	15.4	14522	76
122	Novyy bazar (15/4–31)	701	567	134	0	15.4	10795	75
123	Stritenska (52–63)	210	162	48	0	13.7	2877.0	65.6
123	Stritenska (50, 59, 57, 55, 53, 51a, 49, 47a, 47b)	199	157	42	0	13.7	2726.3	63.7
124	Nyzhnomlynska (1–23)	390	336	54	0	11.1	4329.0	69.6
126	Shevchenka (4–18)	158	130	27	1	11.1	1753.8	69.8
127	Hoholya (26–35)	161	114	42	5	11.7	1883.7	62.3
128	Pushkina (24–45)	427	384	43	0	11.7	4995.9	68.2
129	Haharina (1, 3, 5, 10, 14)	365	296	61	8	11.7	4270.5	72.6
130	May Day Avenue (5–15)	167	128	38	1	11.1	1853.7	67.7
131	Nebesnoyi Sotni (21–44)	1129	856	205	84	11.7	13209.3	78.2
132	Nebesnoyi Sotni (3–32)	1094	816	206	84	11.7	12799.8	80.2
133	Yevropeyska (2–33)	859	638	162	59	11.7	10050.3	77.1
133	Yevropeyska (4, 6, 8, 10)	890	664	158	68	11.7	10413.0	78.0
133	Yevropeyska (18–47)	1062	720	258	84	11.7	12425.4	78.1
134	Pushkina (13–79)	561	477	75	9	11.7	6563.7	72.0
134	Pushkina (42–63)	482	414	62	6	11.7	5639.4	68.5
135	Pushkina (93–87/91)	1317	481	779	57	13.7	18043	77
136	Shevchenka (63a–59)	747	421	297	29	13.7	10234	75
136	Shevchenka (31–54)	412	315	85	12	11.7	4820.4	78.5
137	Dmytra Koryaka (2–43)	468	432	36	0	11.7	5475.6	68.1
138	Sobornosti (39–43)	1405	1020	285	100	11.7	12928.5	81.6
139	Maydan Nezalezhnosti (5, 5a, 3, 3a, 1a, 8, 1, 1a, 1b, 16)	465	378	84	3	11.7	5440.5	71.4

No. the investigated section of the highway	Name of the street (and number of buildings) on which the section of the highway falls	Hourly traffic intensity by vehicleson types on road section, pcs/hour				Coefficient of reduction of hourly intensity to daily, K_{red}	Daily intensity of movement, pcs/day, I_d	Estimated sound level from the traffic flow, dB(A), L_{tf}^{calc}
		Total, N_{hour}	including					
			cars	trucks	buses			
1	2	3	4	5	6	7	8	9
140	Teatralna (42–1в)	270	240	30	0	11.7	3159.0	64.1
141	Sobornosti (42)	658	480	138	40	12.2	802.6	75.6
141	Sobornosti (40)	596	435	124	36	11.1	6604.5	75.1
141	Sobornosti (38)	583	432	116	35	13.7	7987.1	73.8
141	Sobornosti (36)	690	482	166	42	11.7	8073.0	73.5
141	Sobornosti (31)	702	487	170	45	11.7	8213.4	75.5
141	Sobornosti (33)	1023	781	183	60	11.7	11969.1	70.1
141	Sobornosti (35)	967	730	178	59	12.2	11797.4	69.9
141	Sobornosti (37)	962	730	175	57	11.1	10678.2	68.9
142	Yevropeyska (1–21)	170	147	23	0	15.4	2618.0	76.8
143	Vyacheslava Chornovola (2, 2a, 2b, 5)	150	114	36	0	11.7	1755.0	54.2
144	Monastyrska (5–7)	408	333	72	3	11.7	4773.6	78.0
145	Volodymyra Kozaka (2–18)	595	510	77	6	11.7	6961.5	83.9
146	Volodymyra Kozaka (1a, 8, 10)	558	480	72	6	11.1	6193.8	75.1
147	Sholom–Aleykhema (2–45)	715	588	127	0	11.7	8365.5	78.8
148	Pylypa Orlyka (1–36)	108	72	36	0	11.7	1253.6	56.3
149	Panyanka (1–5)	375	348	27	0	11.7	4387.5	68.4
150	Monastyrska (10–59)	474	381	93	0	14.2	6730.8	70.9
151	Lugova (1–39)	331	270	61	0	11.7	3872.7	68.3

Table A.2. Results of measured and calculated values of the noise from vehicles in Shevchenkivskyi district of Poltava

No. the investigated section of the highway	Daily intensity of movement, pcs/day, I_d	Estimated noise level from the traffic flow, dB(A), L_{tf}^{calc}	Measured noise level from the traffic flow, dB(A), L_{tf}^{meas}	No. the investigated section of the highway	Daily intensity of movement, pcs/day, I_d	Estimated noise level from the traffic flow, dB(A), L_{tf}^{calc}	Measured noise level from the traffic flow, dB(A), L_{tf}^{meas}
1	3720.6	72	73	83	497	74	72
2	7335.9	75	74	83	185	70	69
3	3802.5	72	71	84	277	72	70
4	3580.2	72	71.5	84	231	71	70.2
5	3638.7	72	73	84	262	71	70
6	1368.9	68	70.1	85	15	68	67
7	1392.3	68	69.4	85	31	68	67
8	10998	76	74	86	28	68	65
8	7359.3	75	73.4	87	46	68	65
9	12951.9	77	78.2	88	383	73	70.5
10	8342.1	75	73.5	88	327	72	70
11	9512.1	76	74.6	89	43	68	67
12	8353.8	75	74	90	43	68	67
13	13197.6	77	78	91	270	71	70
14	10775.7	76	75	91	140	69	68
15	11009.7	76	74.7	92	339	68	67
15	3440.7	74.8	76	93	216	68	66
16	8845.2	77	76.4	94	431	68	67.5
17	12425.4	76	73.4	94	128	69	68
18	10728.9	76	75	95	154	68	68
19	9933.3	76	74	96	139	68	65
20	9594	76	74	97	20651	77	73

No. the investigated section of the highway	Daily intensity of movement, pcs/day, I_d	Estimated noise level from the traffic flow, dB(A), L_{tf}^{calc}	Measured noise level from the traffic flow, dB(A), L_{tf}^{meas}	No. the investigated section of the highway	Daily intensity of movement, pcs/day, I_d	Estimated noise level from the traffic flow, dB(A), L_{tf}^{calc}	Measured noise level from the traffic flow, dB(A), dB(A), L_{tf}^{meas}
21	8260.2	75	75	97	8116	74	72
22	11512.8	76	77	98	23470	78	77
23	21272	78	75.8	98	21899	78	75
24	4814	72	71.3	99	1987	69	70
25	3635	71	70	100	6137.6	73.8	70
26	5751	73	74	101	5453	78	75
27	2471	70	69.4	101	6439	78	75
28	3408	71	72	101	5041.6	71.2	70
29	3479	71	72	102	986	76	74
30	3436	71	67.9	102	932	76	74.5
31	3365	71	69.8	103	62	68	67
32	9453	75	73	104	92	68	69
33	8672	75	72	105	31	68	65.5
34	7398	74	73	106	55	68	65.5
35	10056	75	73.3	107	55	68	66
36	2740	71	70	108	151	69	65.5
37	2141	69	65.5	108	138	69	66
37	1879	69	66.7	109	68	68	67
37	1630	69	68.3	110	100	68	65.3
38	739	75	73	110	233	71	70
38	9902	75	73	111	3163	78	73
38	7754	74	72	111	8380	78	73
39	6248	73	78	112	422	73	71
39	6165	73	72	113	23746.8	77.6	73
40	22761	78	75.6	114	8220	75	71
40	22819	78	75.8	114	3562	71	70
41	724	68	67.9	114	15046	76	71
42	284	68	65.9	114	11103	75	76
43	270	68	65.8	114	10580	75	72
44	608	68	66.7	115	8763	74	71
45	16263	78	75	116	1586	68	65
46	1001	68	69	117	8208	74	73
47	3573	71	70	118	21879	78	74
48	18264	78	77	118	21440	78	74
48	17304	78	76.9	119	671	68	67
49	16825	78	75.7	120	1329	68	65
49	16087	78	75.9	121	14522	76	74
50	257	68	67	122	10795	75	74
51	175	68	65.8	123	2877.0	65.6	66
52	246	68	69	123	2726.3	63.7	62
54	105	68	69	124	4329.0	69.6	65
55	4118	72	72	126	1753.8	69.8	67
56	554	68	67	127	1883.7	62.3	60
57	710	75	74	128	4995.9	68.2	65
58	13947	78	77.9	129	4270.5	72.6	70
58	17043	78	78.5	130	1853.7	67.7	68
59	344	72	71	131	13209.3	78.2	75
60	322	72	70	132	12799.8	80.2	78
60	266	72	70.3	133	10050.3	77.1	75.5

No. the investigated section of the highway	Daily intensity of movement, pcs/day, I_d	Estimated noise level from the traffic flow, dB(A), L_{tf}^{calc}	Measured noise level from the traffic flow, dB(A), L_{tf}^{meas}	No. the investigated section of the highway	Daily intensity of movement, pcs/day, I_d	Estimated noise level from the traffic flow, dB(A), L_{tf}^{calc}	Measured noise level from the traffic flow, dB(A), dB(A), L_{tf}^{meas}
61	44	68	67.4	133	10413.0	78.0	76
62	55	68	67	133	12425.4	78.1	76
63	266	72	70	134	6563.7	72.0	70
64	33	68	65.7	134	5639.4	68.5	66
65	55	68	67	135	18043	77	75
66	1151	77	75	136	10234	75	73
66	1041	77	78	136	4820.4	78.5	79
67	16432	78	75	137	5475.6	68.1	67
68	200	71	70	138	12928.5	81.6	79
69	154	69	69	139	5440.5	71.4	70
70	139	69	67	140	3159.0	64.1	64
71	62	68	67	141	802.6	75.6	74
72	46	68	67.2	141	6604.5	75.1	72
73	77	68	64.9	141	7987.1	73.8	74
74	192	70	69	141	8073.0	73.5	72
75	479	74	71	141	8213.4	75.5	73
76	12220	78	77	141	11969.1	70.1	68
77	12311	76	75	141	11797.4	69.9	70
77	11928	76	58	141	10678.2	68.9	70
78	12597	76	77	142	2618.0	76.8	71
78	13737	76	75	143	1755.0	54.2	60
79	1124	68	67	144	4773.6	78.0	75
80	369	68	65	145	6961.5	83.9	80
80	301	72	70	146	6193.8	75.1	73.2
80	274	72	71.5	147	8365.5	78.8	75.5
80	329	72	70.9	148	1253.6	56.3	60
81	284	68	67	149	4387.5	68.4	67
82	312	68	65	150	6730.8	70.9	68
83	726	75	72	151	3872.7	68.3	65