



Research paper

An analysis of acoustic climate of an area situated near the expressway, which is a part of international route North-South running through central Europe

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Abstract: The effectiveness of applied means of traffic noise protection can be determined through examining acoustic climate of the areas located near the communication routes. It allows to determine sound level in a specific area and determine the extent that its inhabitants are exposed to the effects of noise. The research and the analysis of the acoustic climate were carried out in the town of Podszosie, located in the vicinity of the S7 expressway. The aim of the research was: to determine the level of noise emitted by traffic on the S7 expressway, to determine the effectiveness of noise barriers installed in a given area, to determine the sound level in the vicinity of properties located in Podszosie, to determine whether the noise level in Podszosie is normal. The conducted research allowed the authors to determine the sound level prevailing in the study area, and to what extent its inhabitants are exposed to the effects of noise and how to prevent it. Showing the scale of the problem posed by noise from road transport. In addition to carrying out activities aimed at reducing its level, society should also be made aware of the harmful effects of its impact.

Keywords: road transport, expressway, acoustic climate, traffic noise

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1. Introduction

Nowadays, traffic noise generated mostly by the means of road transport is a big problem [21, 23]. A thorough analysis of the sources of noise in the vehicles allows to develop appropriate methods of noise protection and their application depends on spatial, economic and technical potential [15, 17–18]. The most popular solution for reduction of noise seems to be application of the noise barriers, which are frequently built near the dual carriageways [4]. Therefore, the effectiveness of such elements and their impact on acoustic climate of the areas that they are supposed to protect should be determined [19, 20, 22]. Apart from noise barriers, other elements of infrastructure are also used in urban areas such as, for example, elevations of levels of the roads or crosswise bulges of a roadway [5, 22]. They are sort of road obstacles criticized by the drivers due to arduousness of avoiding them, however, they have positive impact on acoustic climate.

Based on conducted analysis of subject literature, it was shown that it is a very important element of protection of natural environment and community living near the communication routes [1–3, 6, 8, 9–14]. In the modern human environment, infrasound also plays a very important role [24]. In Poland, research on infrasound noise was conducted by the Central Institute for Labor Protection – National Research Institute (CIOP-PIB), Motor Transport Institute (ITS), Warsaw University of Technology, University of Science & Technology (AGH) [25]. Therefore, the authors decided to conduct the research and check whether examined selected town located near the expressway of high traffic intensity is sufficiently protected against onerous traffic noise. Noise is regarded as environmental pollution and due to this fact, it is necessary to take actions aiming at reduction of the level of such pollution [16].

2. The rates determining noise level generated by the means of road transport

The noise levels generated by the means of road transport are determined with the use of the rates described in the „Environmental Protection Law”. The goal of taking measurements is, above all, determination of equivalent noise level. In the case of sound with determined level A, equivalent sound level will have the value A. In most cases, noise is characterized as undetermined, which means that to determine an equivalent sound level, it is necessary to use an appropriate formula (1):

$$(2.1) \quad L_{Aeq,Te} = 10 \log \frac{1}{T_e} \sum_{i=1}^n (T_i \times 10^{0,1L_{Aeq,Ti}})$$

where:

$L_{Aeq,Ti}$ – averaged equivalent sound level in a time interval T_i [dB],

n – the number of levels $L_{Aeq,Ti}$,

T_e – exposure time.

For equivalent noise level, estimation uncertainty is also determined and marked as $\Delta L_{Aeq,T}$.

The rates applied in determination of noise level are divided depending on the character of conducted research. If the measurements of sound intensity level are supposed to be a reference to run long-term policy of noise protection, the following rates are applied (2):

- L_{DWN} – long-term average sound level A, expressed in decibels and determined for all days of the year with specified hour division for daytime (6 a.m. – 6 p.m.), evening-time (6 p.m. – 10 p.m.) and night-time (10 p.m. – 6 a.m.). L_{DWN} rate is determined using a formula (2):

$$(2.2) \quad L_{DWN} = 10 \log \left[\frac{1}{24} (12 \times 10^{0,1L_D} + 4 \times 10^{0,1(L_W+5)} + 8 \times 10^{0,1(L_N+10)}) \right]$$

where:

- L_N – long-term average sound level A [dB], determined for all night-times of the year (10 p.m. – 6 a.m.).

During examination of acoustic climate, when determination of short-term impact of noise is important, the following rates are applied:

- L_{AeqD} – equivalent sound level A in the daytime (6 a.m. – 10 p.m.) [dB],
- L_{AeqN} – equivalent sound level A in the night-time (6 a.m. – 10 p.m.) [dB].

3. Methodology and method of conducting research on traffic noise in selected points of a town located near the expressway

The research on acoustic climate was conducted based on the document entitled “The reference methodologies of taking periodic measurements of noise level in the environment for roads, railway lines, tramlines, devices in the ports and criteria of location of the measuring points”, which is an annex to the Regulation of the Minister of Environment of January 23, 2003 on the requirements of

taking the measurements of the levels in the environment of substances or energy by a person managing the road, railway line, tramline, airport, port (Dz. U. [Journal of Laws], no. 35, item 308). A place of the research was an area of Podszosie located in the Mazovian province, in the vicinity of national road S7 on the route north-south (E77) running through Central Europe. Modernization included construction of an expressway, including flyovers, footbridges and culverts for animals. Moreover, intersection controlled by light signals, connecting Podszosie and Kępiny was built in the examined area. The intersection is also a connection between expressway and dual carriageway running south to Jedlińsk. The route consists of two main roadways divided into two traffic lanes, 3,50 m wide. An additional traffic lane is an emergency lane, 2,50 m wide. The roadways are separated by energy-consuming barriers. Asphalt road surface is in good condition, without clear damages, potholes and ruts. The road is located in the lowland area and has no elevations or slopes. Parallel to the route S7, the access roads to the premises located in Podszosie, Jedlanka, Kępiny and Mokrosek were built. They are local roads with a single lane for every traffic direction. The condition of asphalt road surface was assessed as good.

The development of examined area (Fig. 1.) in north-east direction includes residential areas with the premises and farms separated by the fence. The nearest premises is situated at a distance of 50 m from the edge of a roadway of expressway S7. Large part of the area has been developed as agricultural land for cultivation and pasture. Therefore, there are no trees, only single bushes, which are not an acoustic barrier that would affect the result of the measurements. During the research, Radom Północ Interchange was being built in the south-east part of Kępina, which will be a part of a ring road of Radom. Therefore, storehouse of machines and building materials were located in the discussed area. At the moment of conducting the research, noise level generated by construction machines was low and had no negative impact on the results of the measurements.



Fig. 1. Podszosie – an area of conducting the research

In the selected section, the means of traffic noise protection in the form of the noise barriers were applied. In this case, „green wall” absorbing noise barriers without plants were installed. Moreover, in two segments of structure of the noise barriers, the noise barriers consisting of reflecting and absorbing panels were placed, whereas, in the area of the intersection, in order to provide better visibility, polycarbonate transparent barriers were applied that were placed on a foundation made of concrete. Under one of the segments, a culvert was placed for water drainage. In a different segment, the doors were installed as a service passage. In accordance with the requirements of sound level in the environment, examined area is classified as an area of single family dwellings, in which permissible level was 61 dB in the daytime (6 a.m. – 10 p.m.) and 56 dB in the night-time (10 p.m. – 6 a.m.).

A digital meter of sound intensity level Voltcraft SL-451 was applied to conduct the research. In accordance with reference methodology, taking correct measurements of sound intensity should be preceded by the measurements of traffic intensity in a specific section of expressway S7. Traffic intensity on the access roads to the premises was marginal, therefore, this value was omitted in general statistics. According to the Regulations, the vehicles participating in the traffic should be distinguished into heavy and light vehicles, as well as based on differences in traffic intensity, correctness of measurement should be assessed. During the measurements, various types of vehicles were recorded and assigned to appropriate classes in accordance with the following pattern:

light vehicles:

- passenger cars,
- minibuses,
- light delivery trucks (DMC < 3,5 t).

heavy vehicles:

- trucks,
- tractor units (with or without a trailer),
- buses, special vehicles (diggers),
- agricultural tractors.

During measurements, no motorcycles and motor bicycles were observed. Traffic intensity of remaining means of road transport was presented on Fig. 2.

Between 6 a.m. and 10 p.m., 21783 vehicles were recorded on the route S7 in the vicinity of Podzósie. National road no. 7, of which part is examined section, plays an important function in national road transport allowing transfer between large cities in northern and southern Poland such as Cracow, Warsaw or Gdańsk. During measurements, many trucks were recorded in overall traffic intensity trucks, 22% on average. The largest group of trucks included tractor units with trailers.

Different working time of the drivers causes that movement of these vehicles is at similar level during the whole day, without substantial deflections (300 vehicles/h).

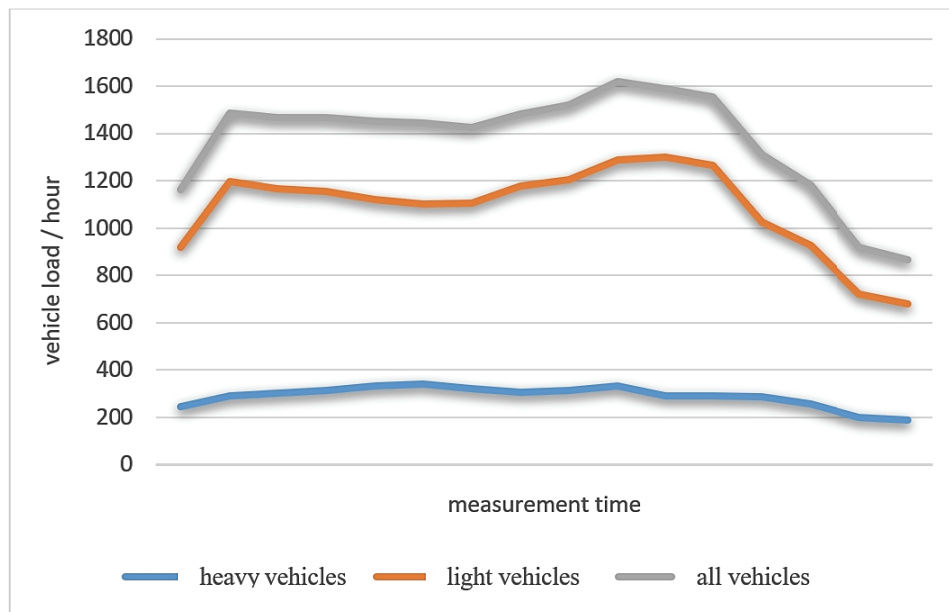


Fig. 2. Traffic intensity in the examined area in Podszosie between 6 a.m. – 10 p.m. [7]

Among light vehicles, the passenger cars were most often recorded. Large part was also light delivery trucks. When it comes to minibuses, the cars of the companies providing intercity transport services were most often recorded. The highest traffic intensity was recorded between 7 a.m. and 8 a.m. (1487 vehicles/h) and 2 p.m. and 5 p.m. (1620 vehicles/h), which is connected with working time of most of the people and resulting need to move in selected hours (Fig. 2).

In accordance with the rules of taking noise measurements specified in reference methodology, time was divided into representative periods during which difference in share of heavy vehicles in all vehicles was not higher than 10%, whereas, in specific hours, traffic intensity was changing by no more than 25%. Determined representative periods were presented in Table 1.

Table 1. The representative periods of noise measurement

Period number	The hour of period commencement	The hour of ending the period
1	6:00	7:00
2	7:00	10:00
3	10:00	12:00
4	12:00	14:00
5	14:00	16:00
6	16:00	18:00
7	18:00	20:00
8	20:00	22:00
9	22:00	6:00

In order to take correct measurements of noise intensity, location of the measuring points was also determined. The geographical coordinates of the points and their distance from extreme lane of the roadway were presented in Table 2.

Table 2. Geographical coordinates and distance of the measuring points from the roadway

Marking of a measuring point	Geographical coordinates	Distance from extreme lane of the roadway [m]
A	51°31'55.9"N 21°05'01.4"E	115
B	51°31'54.0"N 21°05'00.3"E	60
C	51°31'54.6"N 21°05'04.2"E	100
D	51°31'48.2"N 21°05'04.0"E	20
E	51°31'49.9"N 21°05'10.6"E	80
F	51°31'45.5"N 21°05'14.6"E	20

The location of the measuring points on the map was presented on Fig. 3. The measuring points were marked in red. Green line shows position of “green wall” noise barriers. Blue line shows the position of polycarbonate (transparent) noise barriers.



Fig. 3. The positions of the measuring points on the map [7]

The measuring point B was placed in an area closest to traffic lane of the premises, which is partially covered by acoustic shadow generated by short strip of noise barriers in north-west direction. The points A and C, just like the point B was located in Podszosie, but they were placed near the premises located at a distance two times longer from the source of noise than the point B. The point E was placed near the premises in Jedlanka, at a distance of 80 metres from extreme lane of the roadway. The point F was placed at a distance of 10 m from a noise barrier in order to verify effectiveness of generation of acoustic shadow. The point D is located across the route, in the

vicinity of an estate in Kępiny. The goal of taking the measurements in this place was to determine sound intensity level when there are no sound-absorbing barriers.

The comparison of the values measured in the point D with the values measured in remaining measuring points allows to determine effectiveness of the noise barriers.

Before measurements of sound, weather conditions were assessed: air temperature: 18°C, atmospheric pressure: 1007 hPa, humidity: 49%, wind direction: south – west, wind velocity: 2 m/s, no precipitation.

Weather conditions were not an obstacle to take measurements in accordance with reference methodology. The results were presented in Table 3.

Table 3. The average sound intensity levels in the measuring points

Representative period	Duration of the period	The average sound intensity levels in a measuring point [dB]					
		A	B	C	D	E	F
1	6:00–7:00	53,1	56,3	54	68,5	52,5	58,6
2	7:00–10:00	54,6	57,1	54,8	71	54,3	60,2
3	10:00–12:00	54	57	54,2	69,1	53,1	58,6
4	12:00–14:00	54,5	57,2	55,3	70,2	53,3	59,1
5	14:00–16:00	54,2	58,4	55,8	71,1	53,5	59,8
6	16:00–18:00	53,7	57	54,1	70,4	54	60
7	18:00–20:00	54	56,5	55,5	69,2	53,6	59,8
8	20:00–22:00	52,9	56,7	53,9	67,7	53,5	58,4
9	22:00–6:00	52,5	55,1	53,1	66	52	56,8

After taking the measurements, equivalent noise levels in specific measuring points, for daytime and night-time were calculated. The results were presented in Table 4.

Table 4. Equivalent noise level in the measuring points

Indicators	Equivalent noise level in a measuring point [dB]					
	A	B	C	D	E	F
L_{AeqD}	54	57	54,5	69,8	53,5	59,3
L_{AeqN}	52,5	55,1	53,1	66	52	56,8

The highest sound levels in every measuring point were recorded during increased road traffic. Whereas, the lowest measuring values were recorded in the morning and evening, when traffic intensity was noticeably lower. Based on the measurements, it can be said that traffic intensity has direct impact on acoustic climate of the environment.

The highest values of sound intensity were recorded in the measuring point D, which was located at a distance of 20 m from extreme lane of the roadway. Near the measuring point, there weren't any barriers that would enable partial reflection or absorption of acoustic wave, which had impact on the

result of measurement periodically exceeding 70 dB. The point F was located across the route S7, where strip of “green wall” absorbing noise barriers was installed. The location of a measuring point in the acoustic shadow generated by a noise barrier enabled to obtain the results lower on average by 10 dB than in the point D, which shows effectiveness of the noise barriers.

In the point B, recorded measurement of sound intensity was 58,4 dB in the afternoon, whereas, the lowest recorded value was 55,1 dB. The point was located in the vicinity of the premises in Podzrosie at a distance of 60 m from extreme lane of the roadway S7, and noise protection on the way of sound propagation included “green wall” noise barriers along with polycarbonate reflecting noise barriers. In this case, acoustic shadow did not cover proper area because strip of noise barriers was divided by roadway of intersection on the route S7. The points A and C were located in northern part of Podzrosie, at a distance of about 100 m from extreme lane of the roadway S7. Long distance from the source of sound and other buildings on the way of propagation of acoustic wave resulted in reduction of sound intensity level in these areas, by about 2 dB in comparison with the point B.

An analysis of the values of equivalent noise level in specific measuring points showed that the lowest values were recorded in the measuring point E. The point was located in Jedlanka near the premises, 80 metres away from extreme lane of the roadway S7. It is distance shorter than in the case of the points A and C, however, it should be taken into account that the point E is separated from the source of noise by uninterrupted strip of effective noise barriers.

An analysis of the values of equivalent noise level in the measuring points shows whether permissible sound intensity level specified in the Regulation of the Minister of Environment is not exceeded in the examined area. Fig. 4 presents determined noise levels with reference to the values specified by law.

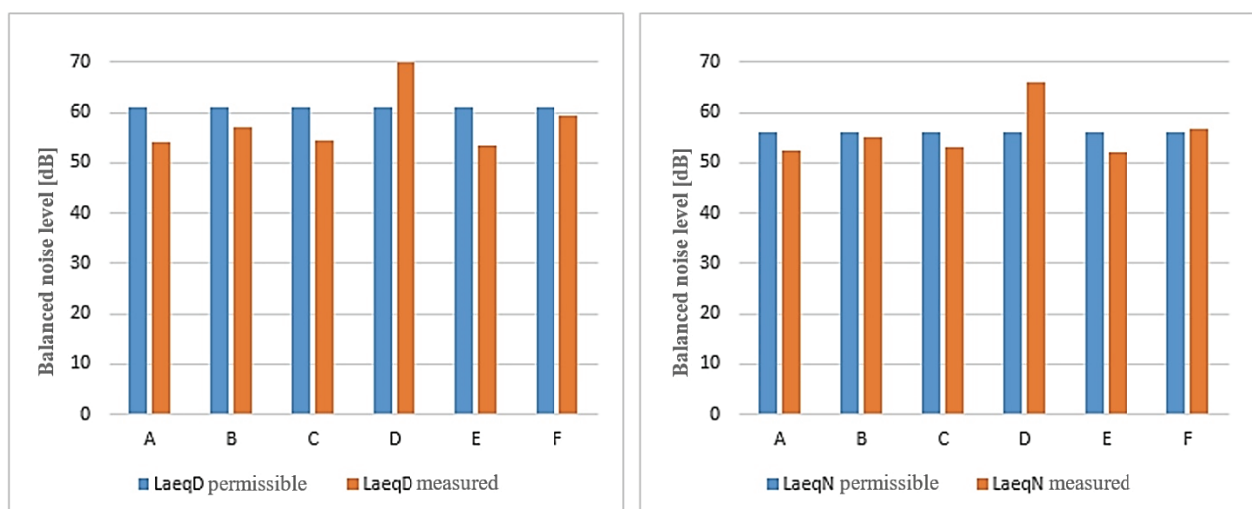


Fig. 4. Recorded values L_{Aeq} with reference to the values specified in the act [7]

In the daytime, noise level was exceeded only in the point D that was separated from the source of sound by noise barrier. In the night-time, equivalent noise level in this point exceeded permissible level by 10 dB. What's interesting, permissible noise level was exceeded for night-time also in the point F, despite the fact that the measuring point was located at a short distance behind the noise barrier. Such state of affairs shows high traffic intensity on the expressway S7. On the other hand, it should be emphasized that permissible noise level in Poland are very rigorous. In general, it can be said that an area of Podszosie is properly protected against noise. However, the noise barriers should be installed also across the route because inhabitants of that premises experience high emission of noise, which has negative impact on their comfort and health.

4. Summary

Nowadays, the problem of noise is treated seriously, therefore, many efforts are being made to improve acoustic climate, especially in the places inhabited by people. The most popular solution is application of the noise barriers with proper location and structure that can reduce sound intensity level by 10 dB. Similar result was obtained in conducted research, which confirms that it is an effective solution. Unfortunately, due to quite high costs in many places, despite appropriate conditions, the authorities resign from application of the noise barriers. Other popular solutions for reduction of noise level include earth embankments and insulating strips of afforestation. In urban areas, the elements reducing traffic such as crosswise bulges, intersections of elevated level or roundabouts are often applied. Whereas, organization of appropriate entry zones allows to reduce traffic.

Conducted research show the scale of the problem, which is noise generated by the means of road transport. Conducted research showed that permissible level of acoustic climate in Podszosie was exceeded in a place not separated from the roadway by noise barrier, as well as in the night-time at a distance of 10 m behind a noise barrier.

General analysis of conducted research suggests that despite high emission of noise by the means of road transport, appropriate acoustic climate through application of the elements of noise protection can be provided for the inhabitants of the areas located near the roads of increased traffic intensity. Noise is an unavoidable phenomenon, especially in the era of economic development. Apart from actions aiming at reduction of its level, people should also be made aware of its harmful impact.

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Analiza klimatu akustycznego obszaru leżącego w pobliżu drogi ekspresowej będącej częścią międzynarodowej trasy północ-południe biegnącej przez Europę środkową

Słowa kluczowe: transport drogowy, trasa ekspresowa, klimat akustyczny, hałas komunikacyjny

Streszczenie:

Problem hałasu jest w obecnych czasach dobrze dostrzegany, w związku z czym dokonuje się wszelkich starań, by poprawić klimat akustyczny, szczególnie w miejscach, które zamieszkiwane są przez ludzi. Najpowszechniejszym rozwiązaniem w tej kwestii jest stosowanie ekranów akustycznych, które przy odpowiednim usytuowaniu i konstrukcji potrafią zapewnić redukcję poziomu natężenia dźwięku o 10 dB. Podobne wyniki osiągnięto w przeprowadzonych badaniach, co potwierdza, że jest to rozwiązanie skuteczne. Niestety, z uwagi na dosyć wysokie koszty w wielu miejscach wciąż rezygnuje się ze stosowania ekranów akustycznych, pomimo odpowiednich warunków. Innymi popularnymi rozwiązaniami, jeśli chodzi o ograniczanie poziomu hałasu są wały ziemne i izolacyjne pasy zadrzewień. W obszarach miejskich często stosuje się również elementy, których zadaniem jest uspokojenie ruchu takie jak poprzeczne wypukłości, skrzyżowania o wyniesionym poziomie, czy ronda. Z kolei organizacja odpowiednich stref wjazdu pozwala na ograniczenie ruchu.

Analiza wartości równoważnego poziomu hałasu w poszczególnych punktach pomiarowych pozwala stwierdzić, że najniższe wartości zarejestrowano w punkcie pomiarowym E. Punkt zlokalizowany był w miejscowości Jedlanka w pobliżu posesji oddalonej od skrajnego pasa jezdni trasy S7 o 80 metrów. Jest to dystans bliższy niż w przypadku punktów A i C, jednak należy mieć na uwadze, że punkt E oddzielony jest od źródła hałasu nieprzerwanym pasmem ekranów akustycznych, które działały w odpowiedni sposób.

Analiza wartości równoważnego poziomu hałasu w punktach pomiarowych pozwala stwierdzić, czy na badanym obszarze zachowane są normy dopuszczalnego poziomu natężenia dźwięku określone w rozporządzeniu Ministra Środowiska. W porze dziennej poziom hałasu został przekroczony jedynie w punkcie D, który nie był oddzielony od źródła dźwięku ekranem akustycznym. W porze nocnej równoważny poziom hałasu w tym punkcie przekraczał dopuszczalne normy aż o 10 dB. Co ciekawe, również w punkcie F zostały przekroczone normy hałasu dla pory nocnej, pomimo, że punkt pomiarowy znajdował się w niewielkiej odległości za ekranem akustycznym. Taki stan rzeczy świadczy o dużym natężeniu ruchu na trasie ekspresowej S7. Z drugiej strony należy zauważyć, że normy hałasu w Polsce są bardzo rygorystyczne. W ogólnym rozrachunku można stwierdzić, że obszar miejscowości Podszosie jest odpowiednio chroniony przed hałasem. Ekran akustyczny powinny być jednak zainstalowane również po drugiej stronie trasy, ponieważ mieszkańcy tamtejszych posesji doświadczają dużej emisji hałasu, co niekorzystnie wpływa na ich komfort i zdrowie.

Przeprowadzone badania ukazują skalę problemu, jaki stanowi hałas pochodzący od środków transportu drogowego. W przypadku przeprowadzonego badania klimatu akustycznego w miejscowości Podszosie, stwierdzono przekroczenie dopuszczalnych norm w miejscu, które nie było oddzielone od jezdni ekranem akustycznym, jak również w porze nocnej w odległości 10 m za ekranem.

Ogólna analiza przeprowadzonych badań nasuwa jednak wniosek, że pomimo dużej emisji hałasu przez środki transportu drogowego mieszkańcom terenów zlokalizowanych w pobliżu dróg o zwiększonym natężeniu ruchu można zapewnić odpowiedni klimat akustyczny poprzez stosowanie elementów ochrony przed hałasem. Hałas jest zjawiskiem nieuniknionym, szczególnie w dobie rozwoju gospodarczego. Oprócz prowadzenia działań mających na celu ograniczenie jego poziomu, należy również uświadamiać społeczeństwo o szkodliwych skutkach jego oddziaływania.

Skuteczność stosowanych środków ochrony przed hałasem drogowym można określić poprzez badanie klimatu akustycznego terenów leżących w pobliżu szlaków komunikacyjnych. Tego typu badanie pozwala na ustalenie poziomu dźwięku panującego na danym obszarze, a jednocześnie określenie w jakim stopniu jego mieszkańcy narażeni są na skutki oddziaływania hałasu.

Przeprowadzono badania wraz z analizą klimatu akustyczny w miejscowości Podszosie położonej w sąsiedztwie drogi ekspresowej S7. Celem badań było: ustalenie poziomu natężenia dźwięku jaki emitowany jest przez ruch uliczny na drodze ekspresowej S7, ustalenie skuteczności działania ekranów akustycznych zainstalowanych na danym obszarze, ustalenie poziomu natężenia dźwięku w pobliżu posesji zlokalizowanych w miejscowości Podszosie, określenie, czy poziom natężenia dźwięku w miejscowości Podszosie mieści się w normie.

Przeprowadzone badania pozwoliły autorom na ustalenie poziomu dźwięku panującego na badanym obszarze, oraz w jakim stopniu jego mieszkańcy narażeni są na skutki oddziaływania hałasu i jak temu przeciwdziałać. Ukazując skalę problemu, jaki stanowi hałas pochodzący od środków transportu drogowego. Oprócz prowadzenia działań mających na celu ograniczenie jego poziomu, należy również uświadamiać społeczeństwo o szkodliwych skutkach jego oddziaływania.

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