Studying Noise Pollution in Vladivostok

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Abstract. The issue of the growing harmful impact of traffic noise on city residents has been relevant for years. Today, protecting the population from exposure to increased noise is essential. Residents of cities are more susceptible to noise. The study objective is to assess the degree of traffic noise impact on the population of Vladivostok. The data obtained will allow identifying the most acoustically unfavorable areas for further research to plan specific noise-reducing measures.

1. Introduction
Technical progress and development of production leading to the increased negative impact on the environment, which inexorably affects human health, deteriorating life quality, requires constant monitoring of the environmental conditions. One of the environmental pollution indicators is noise (acoustic) pollution in cities.

As a hygienic factor, noise is a combination of sounds of various frequency and intensity, which are perceived by human hearing organs and cause an unpleasant subjective perception. Most often, noise accompanies the operation of equipment, therefore, studying issues related to the danger of human exposure to noise has started relatively recently. According to physicians, noise creates a significant load on the human nervous system, causing brain fag and depletion of the cerebral cortex cells, which leads to a general body weakening, suppression of its defenses, and creating conditions for infection. According to some data, at the complex exposure to noise and vibration, the frequency of acute respiratory viral diseases increases by about 2 times [10-13]. An increase in cardiovascular diseases, ulcer disease, and the development of hearing loss is associated with the impact of noise. When continuously exposed to noise, human's attention decreases, dyspraxia occurs, and performance efficiency deteriorates. Therefore, assessing noise as an indicator of environmental pollution is a necessary component of general environmental monitoring [1].

2. The issue of noise pollution in cities
City residents are more susceptible to noise. Studies have shown that the main source of noise in a city is motor vehicles (62.5 % of all cases of detected excess), and construction sites occupy the second place (30 %), followed by industrial sites and non-production facilities (5 %) [9, 16-18]. While the impact of industrial noise is successfully limited by sanitary standards and is constantly reducing, the impact of traffic noise in Russian cities is increasing more and more due to the high motorization rates. Transport noise is among the most dangerous parametric environmental pollutions [8,19-20].
To determine the degree of negative noise impact, along with knowing its source, there should be a clear understanding of the acoustic environment in a city. In the early 2000s, when intensive motorization aggravated the ecological issues of cities, experts started studying the acoustic pollution of Russian cities, and the possibility of using computer technology contributed to a more detailed analysis of the noise level and the wider use of mathematical and cartographic techniques to demonstrate the results. Noise studies have been performed in Moscow [3], Volgograd [4], Belgorod [5], Vladikavkaz, and other cities. Studies recently performed in some Russian cities have shown that 25–40% of the urban population or more already live in areas where noise levels significantly exceed sanitary standards. Further deterioration of the noise regime in cities is expected.

The main source of noise in the areas under study is ground transport [8]. According to AUTOSTAT, over the past thirteen years, the vehicle-to-population ratio in Russia has doubled and amounted to an average of 285 cars per 1,000 RF residents by the beginning of 2018.

Vladivostok is one of the most motorized cities in the country. Every year, the number of road vehicles is constantly increasing, primarily due to the number of cars. Along with the growth of motorization, the level of the noise load on citizens also grows. Here, the type and condition of a vehicle play an important role. Thus, despite the global trend of electrification of cars and urban transport, Vladivostok is just entering the first phase of this process, when the percentage of electric cars is not statistically significant. Also, the cars mainly inflow to Vladivostok from the secondary motor vehicle market of Asian countries, where the quiet vehicle percentage is still not high. As of July 1, 2018, there were 572 cars per 1,000 Vladivostok residents.

The issue of the growing harmful impact of traffic noise on city residents has been relevant for years. In 2005–2008, the FSHI Center for Hygiene and Epidemiology monitored noise pollution in 9 points of the residential areas of Vladivostok. The analysis has shown that the noise level in the residential area on the side of highways exceeds the permissible limit in 100% of measurements. In 2005, the noise level exceeded the permissible limit by 1.8-15.0 dBA (in 2006, by 5-14.50 dBA, in 2007, by 2.0-18 dBA, and in 2008, by 1-21 dBA). The most acoustically unfavorable areas of the city have been identified. These were the transport hubs of St. Lugovaya and territories near the central highways of 10/12 Okeanskii Prospekt and 3 St. Novoivanovskaya.

The increased noise level in the Vladivostok areas under study determines the need for taking preventive measures. Soundproof screens have been installed in some places. However, these measures work only in some areas, in the locations of kindergartens and educational institutions. Much of the city remains uncovered by sound mitigation measures.

The study objective is to assess the degree of the noise impact of vehicles on the Vladivostok population. To achieve the goal, the below tasks should be resolved:
- gathering the noise level data in the area of the streets with the most intensive traffic,
- analyzing the data obtained and identifying the acoustic impact degree,
- identifying the most acoustically unfavorable areas and giving recommendations on reducing the noise impact on the population in these areas.

The noise exposure data gathering methods were analyzed, and an in-situ technique was chosen for the study. Given the rather high accuracy of data, this technique becomes the reference one in simulation as a source of reliable data and is used to check the compliance of the results of other ones.

3. The research methodology
A graphic-analytical technique was used in the study to assess the research results. An assessment of the traffic noise impact on the Vladivostok population was developed in three stages.

The first stage (preparatory). The stage objective was to develop a research program including the choice of research technique, equipment, and roads of passing the key traffic streams, where, according to the plan, the base noise level measuring points would be located.

The second stage was gathering data. At this stage, instrumental noise level measurements and their spatial reference were performed. In the course of measurements, a monitoring database was created.
Thereto, a short-term program for monitoring noise loads along the transport routes of Vladivostok was implemented.

The third stage was a table-top one. At this stage, the data were analyzed, and plots built, using which the points of exceeding the threshold values were identified and increased noise causes determined.

To plot the Vladivostok noise pollution depending on the traffic intensity in the city streets, measurements have been taken at 400 and 80 points along the roads and within the microdistricts, respectively.

When measuring noise, the requirements of GOST 20444-14 Noise. Traffic Flows. Methods for Noise Characteristics Determination; GOST R 53187-2008 Acoustics. Noise Monitoring of Cities; and MUK 4.3.2194-07 Control over the Noise Level in Residential Areas, Residential and Public Buildings and Premises. Methodical Guidelines have been met. According to this State standard, to assess the actual noise regime, draw up a noise map of the road network of a settlement, and develop measures to protect the population from traffic noise, the latter should be measured at a distance of 7.5 m from the first traffic lane axis and a height of 1.2 m from the road surface. The measuring microphone should be directed towards the traffic stream and be at least 0.5 m away from the measurement performer. In narrow streets and roads, the measuring microphone can be placed at a shorter distance from the first traffic lane axis but not closer than 1 m from the walls of buildings, solid fences, and other sound-reflecting structures or terrain elements. Measurements are arranged to ensure the minimum error in results and consider it when correcting the data.

4. The research results
In city areas, measurements were taken 3 times a day at each point: in the morning - from 8:00 to 10:00; in the daytime - from 13:00 to 15:00, and in the evening - from 18:00 to 20:00. The time of measurement was 5 minutes at each point.

Figure 1 shows a diagram of the noise level along the Vladivostok streets in the morning.

![Figure 1. The Noise Level Along the Vladivostok Streets in the Morning.](image)

The maximum permissible noise levels are set depending on the functional purpose of the area exposed to noise (GOST 22283-P-88). In a residential area, 55 dB is considered permissible for the equivalent sound level and 60 dB for the maximum one. For preschool institutions, the permissible sound level is 45 dBA (equivalent) and 60 dBA (maximum). The noise is normal if it does not exceed the standard values set for both the equivalent and maximum levels [6]. Since the residential buildings of most of the investigated streets are located near the road, the permissible sound level set in SNiP
23-03-2003 Noise Protection for areas immediately adjacent to residential buildings, equal to 55 dB and 70 dB, was taken for the equivalent and maximum noise level rates, respectively.

The data analysis has shown that all the studied residential territories adjacent to highways – the main noise impact sources are within the area of increased acoustic impact [14-15].

From the diagram of the noise level in the morning, it can be seen that the maximum value of 92 dBA comes on Makovskogo Street (Fig. 1), which is extremely dangerous for humans. The limit-exceeding values of 80 to 90 dBA come on the Shilkinskaya, Narodnii Prospekt, Lugovaya, and Prospect 100 Let Vladivostoku streets. These are high traffic streets. Along with motor vehicles, railway tracks pass along these streets, which causes increased noise. The noise indicators of only two Ladigina and Neibuta streets are within acceptable limits and do not exceed the maximum allowable level.

Figure 2 a diagram of the noise level along the Vladivostok streets in the daytime.

![Diagram of Noise Levels](image)

**Figure 2.** The Noise Level Along the Vladivostok Streets in the Daytime.

In the daytime, the maximum noise level also comes on Makovskogo Street due to the traffic load. By lunchtime, the noise level decreases in most areas: Verhneportovaya, Borisenko, Okeanski Prospekt, Lugovaya, and Narodnii Prospekt.

Figure 3 a diagram of the noise level along the Vladivostok streets in the evening.
Figure 3. The Noise Level Along the Vladivostok Streets in the Evening.

The diagram of the noise level in the evening shows a decrease in noise in all Vladivostok streets. In-situ observations have shown that this decrease is caused by low traffic speed. The research time coincides with the period of an evening traffic jam when the transport speed is very low.

Researchers of the acoustic level in cities have proved that the equivalent sound level does not regularly increase with an increase in traffic intensity [7]. However, our research has shown that this is true if the traffic speed is reduced slightly. If the traffic speed along the highway is too low, then this leads to a decrease in the noise level. Herewith, gas pollution increases, which significantly worsens environmental conditions.

Fig. 3 shows a map of the Vladivostok areas where the noise exceeds the permissible limits.

Figure 4. The Vladivostok Areas where the Noise Exceeds the Permissible Limits.
When measuring noise along traffic streams, the maximum value of 94.4 dBA in the daytime was detected in Makovskogo Street. This is due to the high-speed traffic since the permitted driving speed on this street is 80 km/h. The lowest average value (70 dBA) was detected in Verhneportovaya Street in the evening when the traffic reduces. The difference between the minimum and maximum levels is 24.4 dB. The reason for the difference is the traffic speed. In the first case, the area is open to traffic since it is a suburban road. In the second case, the area is closed from traffic by residential and public buildings and is remote from it (250-300 m).

Recently, the issue of violating the speed limit at night has become aggravated. Such ‘races’ have a serious impact on noise pollution and the acoustic condition of urban streets. Currently, in Russia, this issue is at the consideration stage. The mechanisms for combating the ‘night hooligans’ have not yet been developed. Therefore, the increased night noise observed in areas adjacent to highways with the high-quality road surface is just caused by the urban racers disturbing the public order.

5. Recommendations
Today, protecting the population from exposure to increased noise is essential. Since the noise load equally depends on both the traffic characteristics and on the area layout, it is advisable to take the below measures to reduce the noise:

- increasing the distance between the noise source and the protected object,
- using acoustically transparent screens,
- using special anti-noise planting,
- applying various layout techniques, rational location of microdistricts.

When planning urban quarters, it should be considered that at a closed housing type, only intra-quarter areas are protected, and the external facades of buildings fall into unfavorable conditions, therefore, such a highway positioning is undesirable. The most expedient is free housing protected from the street side by planting and shielding buildings of temporary residence (shops, canteens, restaurants, ateliers, etc.). Sunken highways also reduce noise in the surrounding area.

6. Conclusion
The represented data may serve as a basis for drawing up strategic noise maps required to identify the noise pollution sources, assess the life quality of the residential area population, and develop measures to protect the population from harmful acoustic impacts and ensure environmental safety.

The data obtained allow identifying the most acoustically unfavorable areas for further research to plan specific noise-reducing measures.

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