Development of a methodology for assessing the impact of vehicles on the acoustic environment

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Abstract. Currently, the population of cities is in constant acoustic discomfort, both in production and transport, and in everyday life. Noise sources in cities are diverse. The reason for noise in cities can be mechanical engineering, light and construction industries, while the main source of noise is transport. Its share is 70-80% of the total background noise transmitted through the atmosphere. On major highways, the noise level is 85-92 dB with a maximum sound pressure in the frequency range of 400-800 Hz. In an industrial city, a high percentage of freight transport on highways is common. An increase in the total traffic flow of trucks, especially heavy trucks with diesel engines, leads to an increase in noise levels. Therefore, the development of methods to reduce the noise impact of various man-made sources on the environment of urban areas has become urgent. According to the developed method, you can determine the noise level near the city's roads.

The critical value of the sound level in the premises above 24 dB, and in the city above 34 dB is taken as the reference point for the presence of noise. Residential premises where the sound level exceeds 70 dB during the day and 55 dB at night are considered emergency, and their operation is unacceptable. Heavy noise is generated by rail transport. Even at a distance of 200 m from the railway line, its level is approximately 60 dB. An increase in train speeds also leads to a significant increase in noise levels in residential areas located along railway tracks or near marshalling yards. The maximum sound pressure level at a distance of 7.5 m from a moving electric train reaches 93 dB, from a passenger train 91 dB, from a freight train 92 dB. At a speed of 35 km/h, the electric train creates noise of 82 dB; 43 km/h 84 dB; at 55 km/h, the sound level increases to 89 dB [1-7]. Table 1 provides a scale for evaluating the noise level.

| Degree of noise pollution | Noise level, dB |
|---------------------------|----------------|
| Noise is comfortable      | <35            |
| Normal                    | 35-50          |
| Average                   | 51-60          |
| Strong                    | 61-70          |
| Emergency                 | >70            |

Table 1. Scale for evaluating the process of noise pollution of urban land.
The main source of railway noise is the impact of cars when moving on joints and uneven rails. The movement of locomotives, freight trains, dispatching communications, and locomotive signals can also cause acoustic disturbances in residential areas. Of all types of urban transport, the tram is the most noisy. Steel wheels of a tram when moving on rails create a noise level 10 dB higher than the wheels of a car when in contact with asphalt. The tram creates noise loads when the engine is running, doors are opened, and sound signals are given. The high level of noise from tram traffic is one of the main reasons for the reduction of tram lines in cities [8-16].

Airports are powerful sources of noise that are associated with acoustic pollution in a large area. Especially intense noise is created by aircraft during takeoff. For example, the noise level at a distance of 1 km from the runway when taking off a small aircraft reaches 107-110 dB. The noise level in cities increases by about 0.5-1 dB per year due to population growth, increased vehicle speeds and traffic intensity, and in some large cities the increase in acoustic load reaches 2 dB per year. Residential premises, especially those located in high-rise buildings, have a large number of "internal" noise sources: working elevators, fans, pumps, televisions, tape recorders can create noise with an intensity of 70 to 95 dB. A loud conversation on the phone is a source of acoustic impact with an intensity of up to 70 dB [17-25].

Strong noise negatively affects the human hearing organs. First of all, the perception of high sounds worsens, and then low ones. Constant exposure to it reduces the ability to work, can cause neuroses and many other diseases. Older people are most sensitive to noise. While approximately 46% of people under the age of 27 respond to noise, 72% of people aged 58 and older respond to it. People are more susceptible to acoustic effects at night [26-33].

Table 2 shows the distribution of the main types of urban noise by the sound levels created, as well as (as a percentage) by the number of noise complaints received from the urban population.

| Type of noise | Sound level, dB | Public complaints about noise, % |
|---------------|-----------------|---------------------------------|
| Household     | 75-85           | 12-22                           |
| Production    | 75-80           | 8-12                            |
| Transport     | 85-100          | 66-80                           |

Contrary to popular belief, there is no habituation to noise. The human autonomic nervous system reacts negatively to any noise. Doctors have found that the physiological and biochemical adaptation of a person to noise is impossible. Sudden high-frequency sounds are especially difficult to tolerate. Acoustic pollution of the environment affects people no less than the destroyed ozone layer or acid rain. Long-term noise exposure is considered as one of the factors that cause increased morbidity. Thus, changes in the functional state of the central nervous and cardiovascular systems, coronary heart disease, hypertension, and increased cholesterol in the blood are more common in people living in noisy areas [34-41].

The values of the equivalent noise level $L_{eq}$, affecting a person, from various man-made sources should not exceed the limit values established by sanitary standards for specific conditions. Noise above 80 dB is harmful to the human body, and at its level above 90 dB, partial hearing loss is possible. The pain threshold is in the range of 120-130 dB. Industrial noise affects a person while they are in the workplace. In administrative premises and institutions, the noise intensity reaches 40-60 dB, and the operation of equipment in industrial premises is accompanied by noise up to 70-80 dB. The greatest acoustic load is experienced by workers in the workshops of various factories and repair enterprises of the city. For example, in blacksmith shops, hammers and mechanical processes are sources of pulsed shock noise with a sound pressure level of up to 130 dB, in mechanical shops, the work of metal-cutting equipment produces noise of 85-100 dB (in some cases, 105-114 dB), riveting work creates noise with a level of 115 dB, grinding and drilling 88-118 dB [42-49].
Table 3 shows the sources of traffic noise that are available in the city with an indication of the sound levels created during their operation.

### Table 3. Sources of urban noise.

| Noise source       | Noise level, dB |
|--------------------|-----------------|
| Railway train      | 80-100          |
| Trolleybus         | 71-84           |
| Passenger car      | 60-75           |
| Bus                | 80-95           |
| Low-power truck    | 75-79           |
| Heavy duty truck   | 80-87           |
| Motorcycle         | 80-100          |

Transport noise has the greatest negative consequences for the population than industrial or household noise, since its scope is much wider, and the physical parameters that characterize the impact of noise on the human body are incomparably higher. The noise generated by vehicles impairs the quality of human and animal habitat in the areas adjacent to the road. Noise affects the human nervous system, reduces the ability to work, reduces the resistance to cardiovascular diseases [50-56].

In conditions of intensive motorization, the formation of zones of acoustic discomfort in cities is mainly determined by vehicles moving along highways. The problem of traffic noise is gaining social significance, becoming one of the most important problems of road operation and traffic management. The noise impact that the population experiences in the zone of influence of roads is almost constant and cannot be regulated by the people themselves without carrying out cardinal planning measures (for example, replacing Windows with simple glass with noise-proof ones). The noise impact of vehicles is experienced by people who are located (including residents) in the zone of influence of roads and are directly in the vehicle (drivers and passengers). Requirements for the noise characteristics of cars are constantly being tightened, and now in many countries, regulations have been introduced to limit the noise of vehicles [57-65].

The sound pressure level is determined by the formula:

$$L_p = 10 \log \left( \frac{P}{P_o} \right),$$

where $L_p$ - sound pressure level, dB;

$P$ - intensity of the active noise, W/m²;

$P_o$ - sound intensity corresponding to the audibility threshold at a sound frequency of 1000 Hz, is assumed to be equal to 10-12 W/m².

From formula (1), it can be seen that an increase in the sound intensity by 10 times gives an increase in the sound level by 10 dB.

The value of the equivalent level of traffic noise generated on the road in use depends on transport factors (intensity, composition, use of sound signals, etc.), road factors (longitudinal profile (ascents, descents), the presence and type of intersections and junctions, roughness, evenness, cross-section profile, the presence of embankments and recesses, dividing strips, stopping points for transport, etc.), natural and climatic factors (atmospheric pressure, humidity, air temperature, wind speed and direction, turbulence of air flows, precipitation) [66-69].

Predicting the equivalent level of traffic noise at a distance of 7.5 m from the axis of the nearest lane is allowed to carry out an approximate formula:

$$L_{ap} = 50 + 8.8 \log N + F,$$

where $L_{ap}$ - noise level at a distance of 7.5 m from the axis of the near lane, dB;

$N$ - estimated hourly traffic intensity, auth./h;
F - background noise level, taken according to local sanitary and epidemiological surveillance authorities.

The equivalent noise level in a roadside lane is determined by the formula:

\[ L_{eq} = \Delta L_{sp} + \Delta L_{lp} + \Delta L_4 + \Delta L_d + \Delta L_{dies} - \Delta L_L + F . \]  

(3)

where \( \Delta L_{sp} \) - speed correction; 
\( \Delta L_L \) - correction for longitudinal slope; 
\( \Delta L_d \) - correction for the type of coverage; 
\( \Delta L_{dies} \) - correction for the number of diesel cars; 
\( \Delta L_L \) - amount of noise reduction depending on the distance \( L \) in meters from the last lane; 
\( K_r \) - coefficient that takes into account the type of surface between the road and the measurement point.

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