Analysis of the Acoustically Noise Situation in an Urbanized Area in the Presence of Vehicular and Industrial Noise

V V Bulkin¹, T D Khromulina², I N Kirillov³

¹Vladimir State University named after Alexander Grigoryevich and Nickolay Grigoryevich Stoletovs, Murom Institute, 23, Orlovskaya str., Murom, 602264, Russia
²Vladimirteplogaz, Murom Branch, 110-a, Pervomayskaya str., Murom, 602263, Russia
³Murom Plant of Radio Measuring Instruments, 2, Karacharovskoye shosse str., Murom, 602200, Russia

E-mail: vvbulkin@mail.ru

Abstract. Acoustic noise is now becoming one of the important problems of the technosphere. The source of such noise in the streets of large cities is mainly motor transport, as well as industrial enterprises located in the city and construction sites. In the report some results of monitoring of acoustic pollution of the big industrially developed cities (on the example of the city of Murom) are considered. Monitoring is carried out with the help of a combined ecology-meteorological system. The measurement errors due to the standard octave analysis procedure with a control at central weighted frequencies are analyzed. It is shown that the application of the full spectral analysis using the fast Fourier transform allows us to compensate for these errors. The features of the construction of the measuring channel used in the monitoring procedure are considered. Some results of analysis of the spectrum and levels of acoustic noise on the streets of the city at different periods of the day are given. It is shown that in the most heavily loaded areas of the city, combining the activity of traffic flows and the functioning of industrial enterprises, the maximum values of sound pressure level of acoustic noise can reach 100 dB. Both maximum and average values of sound pressure are analyzed from the point of view of their compliance with the current sanitary norms. The conclusion is made that the actual noise levels exceed the maximum permissible levels for open spaces.

1. Introduction

The problem of noise becomes one of the main problems of modern urbanized space, occupying the third most important place among all environmental polluters of any big city. Numerous studies show that acoustic noise has a significant adverse effect on the psychological and biological health of a person, the state of the social environment [1].

In large, and medium-sized cities, noise caused by active traffic is a big problem. According to official bodies in the Russian Federation, more than 35 million people live in conditions of such acoustic discomfort. From the State Report "On the state and protection of the environment of the Russian Federation in 2011" it follows that in the settlements crossed by federal and regional highways, in the daytime the noise level exceeds the permissible values by 25 dB.

In addition, on the territory of modern large cities there are industrial enterprises, which are also a source of acoustic noise.
An additional factor affecting the nature of the noise signal propagation is the meteorological situation in the region under consideration, which always has characteristic local features [2].

The report discusses the results of the acoustically noise pollution study in the characteristic zones of the urban environment (on the example of the city of Murom), caused both by the movement of road transport and the work of industrial enterprises located in the city.

2. Peculiarities of the noise environment in the urban realm
The analysis of the acoustically noise situation in the characteristic areas of Murom was carried out within the framework of contracts concluded with the City Administration. Due to the fact that the city was originally one of the industrial centers of the Vladimir region, and enterprises of various profiles are located within the urban environment, special attention was paid to the areas of combination of residential and industrial areas.

2.1. The results of one of the measurements made in such a zone
This territory is chosen because the border of the plant directly adjoins the pedestrian zone in the area of the busy highway passing through the city center and connecting several areas of the central region of the country. Even with the organization of a bypass road, this highway is actively used by heavy trucks, including for transportation of products produced by the city enterprises. The other side of the highway is the boundary of the residential area. In addition, nearby there is a checkpoint to the territory of the enterprise, through which heavy trucks carry out finished products. Thus, industrial and residential areas converge in this zone there is an intensive movement of passenger, public and heavy vehicles, as well as pedestrians.

In Figure 1 an example of the nature of the noise level change in a certain area is shown. It can be seen that the noise has a non-permanent character and its level can vary within large limits. In addition, there are amplitude emissions, the time and level of which are nondeterministic. In this case, the duration of the amplitude noise burst is also nondeterministic.

![Figure 1. The nature of the change in the level of acoustic noise in (for a period of 18 seconds).](image)

As it can be seen from the spectrogram, in addition to the general background noise, there are a lot of non-constant narrow-band amplitude emissions related to different frequencies, which certainly complicates the processing of the information obtained.

The complexity of processing is as follows. In traditional measurements, the sound level meter is actually a microphone sensor and a voltmeter, the indicator of which is calibrated in decibels. Electrical filters are used to measure sound pressure levels in octave or fractional octave (one-third
octave) frequency bands. The size of the selected range and the weighted frequencies corresponding to these ranges are determined by the R10 row in accordance with GOST R 53188.1-2008 (IEC 61672-1:2002) [3].

This measurement principle certainly introduces an unpredictable error, since any voltmeter, regardless of whether it is analog or digital, shows the average value of the voltage (amplitude).

2.2. Practical evaluation of a possible measurement error

A practical estimate of this error can be illustrated by a cut of one of these spectrograms shown in Figure 2.

Vertical lines allocate boundary frequency bands for a conventional sound level meter with a one-third octave filter, into which the areas with an amplitude spike fall. It is marked in two sub-bands of 2-2.5 kHz and 2.5-3.15 kHz according to the R10 row. The horizontal lines show the averaged values of the amplitudes in these ranges, i.e. these are the values that are fixed by a conventional sound level meter.

It can be seen from the figure that the difference between the spike amplitude and the average value that the sound level meter does not register can reach 20 dB.

To assess the impact of this discrepancy on the assessment of the real situation in the residential area, we will estimate the attenuation of the sound of pure tone on the terrain, taking into account the real meteorological conditions.

Omitting intermediate calculations, we find that the attenuation coefficient of sound at a given frequency is more than 11 dB/km, and an error in estimating the range of possible propagation of such a sound signal can reach 1 km in a quiet atmosphere under normal atmospheric conditions.

![Figure 2. A mechanism for estimating the noise level using a conventional sound level meter.](image)

3. Noise control results

With the aim of eliminating these shortcomings, an ecology-meteorological system was developed whose main advantage in comparison with the measurement scheme by a standard noise level meter is that the transition from the amplitude-time characteristic to the amplitude-frequency one is implemented on the hardware level by the Fast Fourier Transform (FFT) algorithm. The use of FFT makes it possible to observe and monitor not average values in a given frequency band, but narrowband amplitude spikes at various frequencies, including those located at the edges of the octave (fractional octave) range. In addition, the measuring channel under consideration makes it possible to determine frequency values and amplitude of the peaks with greater accuracy than in the standard scheme. The principles of the system construction are considered in [4, 5].
Figure 3 and 4 show the spectrum and noise level in the morning and night. In the first case, the spectra of average and maximum values of the noise level are shown. In the second case, due to the lack of intensive movement, only average values that are slightly different from the maximum values are shown. In all cases, the control period was 1200 seconds.

The presented graphs clearly show that in the frequency range of 125-2000 Hz the maximum noise values (upper spectrogram) exceed the "sanitary" norm of 85 dB and in some places it approaches the level of 90 dB.

At the same time, the average values of the noise of the measurement period (the lower spectrogram) only in a certain part of the frequency range (about 1000 Hz) reach the level of 80 dB. And in the most sensitive part of the range of 1000-4000 Hz for a person, smoothly decrease from 80 to 60 dB.

At night, due to the lack of intensive traffic, the noise level even in peak values does not exceed 50 dB, which according to the conventional scale corresponds to a normal conversation and is designated as "Clearly audible". The presence of such a spike in the low-frequency part of the range can be explained, for example, by the presence of air movement or beating of signals in the oncoming traffic of vehicles. Such spikes can also be explained by the influence of the work of the industrial enterprise located in the measurement zone. In any case, the presence of a spike in this zone of the range must also be questioned because of the limitation of the guaranteed frequency range of the microphone used at a frequency of 20 Hz and higher.
In general, the level of noise at night complies with the sanitary standards in terms of the permissible maximum in the period from 23 p.m. to 7 a.m. Consequently, it can be assumed that in nearby houses, the noise from vehicles is practically not manifested.

Since the current sanitary standards [6], which determine the permissible noise level in the residential areas, establish sound pressure levels for weighted average octave band frequencies, a comparison of the noise level values at these frequencies with the established standards is made (see Table 1).

Since the noise level was measured in an area directly adjacent to the residential inner yard and the children's preschool establishment, the permissible sound pressure levels used for comparison were chosen for the areas immediately adjacent to residential buildings, polyclinic buildings, dispensary buildings, rest homes, boarding houses, boarding homes for the elderly and disabled, preschool institutions, schools and other educational institutions, libraries. In addition, the comparison with the norms established for territories directly adjacent to the buildings of hotels and hostels is provided (indicated in the table, respectively, in blocks of lines "1" and "2").

Table 1. Comparison of the received values of noise levels with the established norms.

| Frequency, Hz | 31 | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 |
|---------------|----|----|-----|-----|-----|------|------|------|
| Maximum value, dB | 55 | 67 | 78 | 86 | 89 | 92 | 89 | 77 |
| Average value, dB | 37 | 54 | 64 | 71 | 75 | 80 | 71 | 59 |
| Permissible sound pressure level, dB | 90 | 75 | 66 | 59 | 54 | 50 | 47 | 45 |
| Exceedance of maximum level, dB | -35 | -8 | 12 | 27 | 35 | 42 | 42 | 32 |
| Exceedance of average level, dB | -53 | -21 | -2 | 12 | 21 | 30 | 24 | 14 |
| Permissible sound pressure level, dB | 93 | 79 | 70 | 63 | 59 | 55 | 53 | 51 |
| Exceedance of maximum level, dB | -38 | -12 | 8 | 23 | 30 | 37 | 36 | 26 |
| Exceedance of average level, dB | -56 | -25 | -6 | 8 | 16 | 25 | 18 | 8 |

The "-" sign shows that the actual value of the sound pressure does not reach the established specifications.

4. Conclusions
The obtained results allow us to conclude that in areas with active motor traffic in the city of Murom, the excess of the permissible sound pressure level, especially in the range of the highest sensitivity of the human ear (1000-4000 Hz), is significant and reaches 40 dB and higher in the maximum level, and 30 dB by the average level. In the low-frequency range (31-125 Hz), the norms are generally not exceeded (taking into consideration the permissibility in some cases of exceeding the level to 10 dB). To reduce the noise level at medium frequencies, it is necessary to use a set of protective measures.

5. References
[1] Bulkin V V 2016 Ecological Systems and Devices Noise pollution of industrial cities (the example Murom) (Moscow: Nauchtekhlitizdat Publishing House) pp 18-21
[2] Smit K 1975 Principles of Applied Climatology (London: McGraw-Hill Book Company (UK) Limited)
[3] IEC 61672-1:2002 Electroacoustics - Sound level meters - Part 1: Specifications (MOD)
[4] Bulkin V V and Kirillov I N 2014 Passive-active monitoring system of acoustic contamination of the local urban area Radio- and Telecommunication Systems 4 pp 48-55
[5] Bulkin V V and Kirillov I N 2017 The device for controlling the propagation of acoustic noise in a residential area Patent RF № 2618486 (Published: 03.05.2017)
[6] Sanitary norms 2.2.4/2.1.8.562-96 1996 Noise in workplaces, in residential, public buildings and in residential buildings (Moscow: Goskomsanepidnadzor) p 8
Acknowledgments
The work was supported by the grant of Russian Foundation for basic research №18-38-00909. The work was supported by the municipality of the city Murom.