Geoinformation Technology for Estimation of Geoecological Risks from Technogenic Noise

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Abstract – **The solution of the modern problem of estimation and preventing geo-ecological risks caused by traffic noise and other natural and technogenic sources is considered. A complex theoretical and experimental approaches are proposed and analyzed in order to solve the problem of reducing geoecological risks from traffic noise.**

Index Terms – **Technogenic noise, geoecological risks, assessing and preventing, numerical simulation, experimental research**

I. INTRODUCTION

CURRENTLY, there is an acute problem of assessing and preventing geo-ecological risks caused by traffic noise and other natural and technogenic sources.

The level of noise pollution is among the most important indicators characterizing the comfort of living in urban areas [1]. The World Health Organization has conducted a study and made estimates of the noise levels to which residents of European countries are exposed. According to these data, about 40% of Europeans are exposed to noise levels exceeding 55 dB during the daytime, and 20% are exposed to noise levels exceeding 65 dB [2]. This is facilitated by the conduct of active building work, an increase in the number of cars, as well as the conduct of various landfill and quarry explosions [1]. There are also noises of a natural nature (from electrical discharges and sudden fluctuations in atmospheric pressure, hurricanes, etc.).

The problem of harmful effects on the environment increases sharply in the area of low and infra-low frequencies, the most ecologically dangerous for humans, as well as the most destructive for large structures (bridges, buildings, industrial premises, etc. The latter is determined by the fact that in the area of infra-low frequencies there are resonant frequencies of structures.

Vibrations corresponding to low frequencies are also the most dangerous for the human body, as they can coincide with its natural frequencies. Thus, the frequency of contraction of the heart lies in the frequency range of about 1-2 Hz. The frequency at which the electrical activity of the brain occurs is about 0.5-20 Hz.

This is dangerous because if the external oscillation frequencies coincide with the internal frequencies of the body, the latter can be amplified negatively affecting human health.

In particular, published studies have shown that exposure to frequencies of about 12 Hz at a level of about 85-110 dB may cause seasickness and dizziness. As a result, exposure to frequencies around 12 Hz at the same level leads to anxiety, uncertainty and can even cause anxiety. For the eyeballs, a frequency of about 19 Hz is characteristic, exposure to which can lead to visual impairment [3].

Vestibular disorders of the brain are associated with exposure to infrasound at a frequency close to 6 Hz.

Low-frequency waves are weakly absorbed, which is why they have a high penetrating ability. As a consequence, they can spread over considerable distances. In transport processes, along with infrasound, sounds of the acoustic range, located at high frequencies, are usually distributed. For this reason, infrasound is less noticeable, but this does not make it less dangerous. The following thresholds for the impact of infrasound on a person have been established: Infrasounds with an intensity of 155 - 180 dBA are threshold ones that carry a potential danger to human life. The safety threshold is considered at an infrasound level of 90 dBA [4].

The above determines the need to solve, in a broad sense, the problem of assessing, predicting and reducing environmental risks generated by natural and technogenic noise.

II. PROBLEM STATEMENT

The levels of geo-ecological danger for the social environment and humans are determined by several factors. One of the important are the meteorological effects of the infrasound propagation [5,6].

In particular, using the vibration method, the directivity effects of the acoustic wave field generated by sources with an infra-low frequency range are estimated. Ones are determined by the influence of the wind, which in turn is described by characteristics such as speed and azimuth direction. As a result of the influence, a spatial redistribution of the infrasound intensity arises, which can lead to a multiple increase in the latter in a certain azimuthal direction (the effect of spatial focusing of acoustic energy). Obviously, this may be associated with the destructive effects of infrasound [1].

Another problem from the considered complex is related to noise reduction using shielding obstacles in the path of

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infrasound propagation [7-10]. As a screen, forest belts planted along the edges of large highways are common [11].

Frequency-dependent absorption effects were numerically simulated and appropriate recommendations were developed for effective absorption of infrasound in the model of boundary environments "atmosphere-forest-land" [11].

The problem of separating ecologically hazardous low-frequency components from various types of transport from the general broadband spectrum of transport noise is posed. The solution of problems is carried out using a software-analytical complex for recording and processing seismic and acoustic noise vibrations, generated by various types of heavy equipment: automobile, railway, tracked.

The time-frequency spectra are obtained, characterizing the main amplitude-frequency regions of noise concentration.

III. THEORY

Multivariate numerical model of noise reaction. One of the criteria for noise reaction is determined by the magnitude of geoecological risks. Geoecological risks are assessed by specific energy density:

$$E = \frac{1}{\rho c}\int_0^T p^2(t)dt \,, \qquad (1)$$

where ρc — specific acoustic resistance of air, equal to 42g/(cm^2 s); ρ - density of the environment; c – speed of sound in the environment; $p(t)$ — acoustic pressure recorded at the output of the acoustic sensor; T is the duration of the acoustic vibration [12].

For a person, the value of the specific energy density up to 3 J/m^2 is safe. The defining parameter in (1) is the energy characteristic of the acoustic reaction associated with the external acoustic pressure at a given frequency. The latter is an integral parameter that depends on a number of factors.

The propagation of traffic acoustic noise in the atmosphere and seismic noise in the ground is influenced by a number of factors, including meteorological factors, inhomogeneities in the structure of the environment for the propagation of seismoacoustic vibrations, natural and artificial heterogeneity of the earth's surface, frequency-dependent characteristics of the vibrations themselves.

To describe the multivariate model of integral pressure, the energy balance equation is used:

$$P_\Sigma(t,f,r) = P_v(f) + P_1(r) + P_2(e,\tau,\omega,\phi) + P_3(1/r) \,, \qquad (2)$$

where $P_\Sigma(t,f,r)$ is the pressure at the registration point at a distance r from the source; $P_v(f)$ - frequency dependent acoustic pressure developed by the source; $P_1(r)$ - absorption of infrasound by distance, determined by the inhomogeneity of the atmosphere and the cover of the Earth's day surface; $P_2(e,\tau,\omega,\phi)$ - pressure at the registration point as a function of meteorological parameters: relative humidity, temperature, wind speed and direction, angle ϕ between wind direction and wave front from the source; $P_3(1/r)$ - pressure as a result of the spherical divergence of the wave front;

Obtaining estimates (2) in an analytical form encounters difficulties due to the lack of completeness of a priori information about meteorological conditions along an extended path of propagation of acoustic vibrations. This also includes factors associated with the characteristics of absorption of the energy of acoustic vibrations due to the presence of forests, snow cover, geological irregularities (hills, mountains) of the earth's surface, etc., which occur along the path of propagation of acoustic vibrations.

IV. EXPERIMENTAL RESULTS

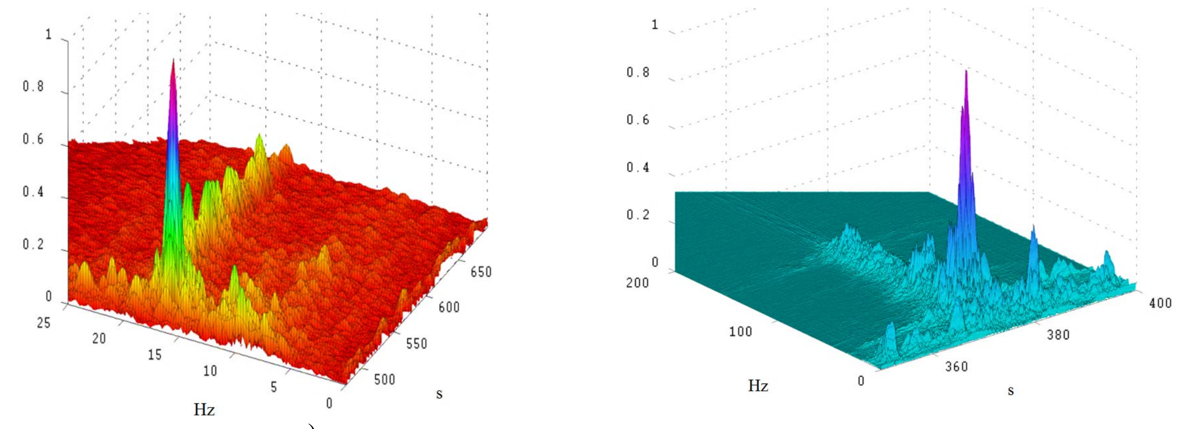
To obtain noise estimates, experiments were carried out to record seismic and acoustic noises generated by various types of moving transport equipment - railway, automobile, tracked.

The problem of separating characteristic low-frequency components in relation to various modes of transport, which are the most environmentally threatening for humans, from the general broadband spectrum of transport noise is posed. Its solution is carried out on the basis of using the method of spectral-temporal analysis (STA) of technogenic noise records obtained in field experiments. STA is realized in the form:

$$F(k,l) = \sum_{n=0}^{N-1} S_l(t_n)\exp(-i\frac{2\pi nk}{N}), l = 1,...,L \,, \qquad (3)$$

where L is the number of sections of duration $\Delta T = N \cdot \Delta t$ each, into which the sought noise signal $S(t)$ is divided, Δt is the signal sampling interval. Thus, (3) is a spectral-time function (STF). The spectral-time functions (STF) of heavy transport noise are obtained, which make it possible to estimate the dynamics of noise in time and space, to estimate their main spectral modes.

Based on the results of processing, the features of the spectrum behavior are distinguished. Thus, in relation to such an inhomogeneous medium as the earth, the main mode of the spectrum as a function of distance is



a) b)

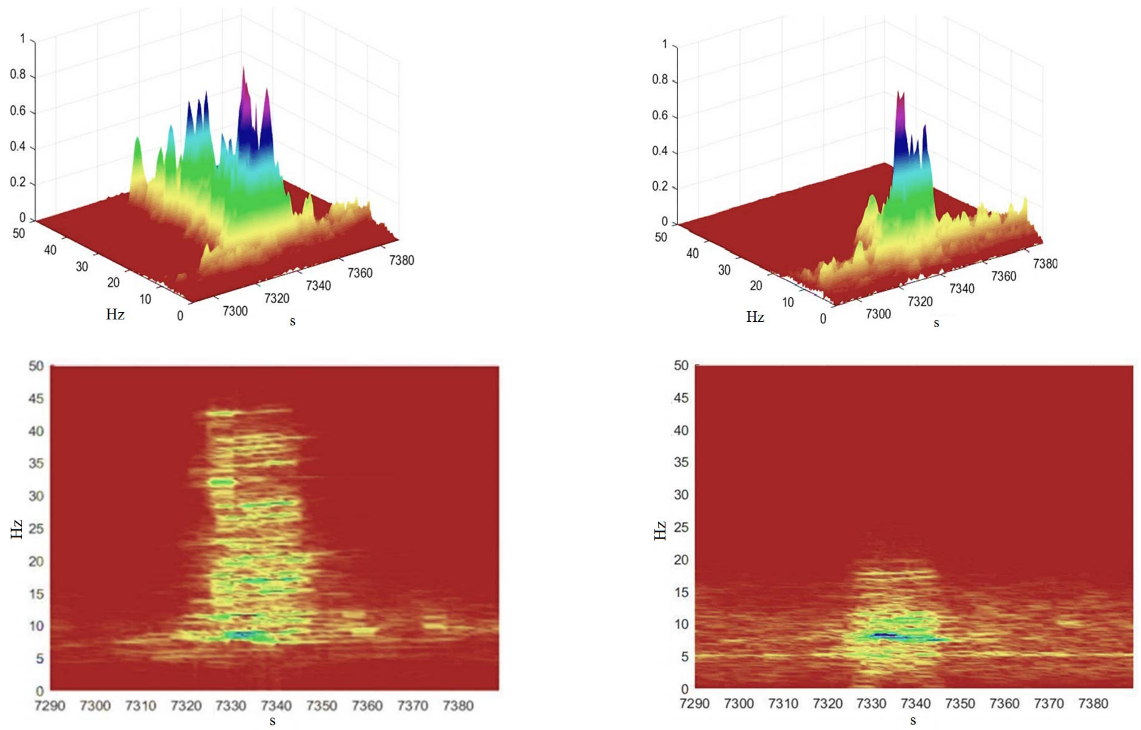
Fig. 1. Spectral-time functions (STF) of seismic noise: a) - tracked transport; b) - heavy truck KAMAZ.

described by a pulsating fading exponent. In particular, this is confirmed by the behavior of the STF mode of moving tracked transport, shown in Fig. 1a.

The importance of mode here is in the area of 17.8 Hz. The pulsation frequency of the main mode is about 0.03 Hz.

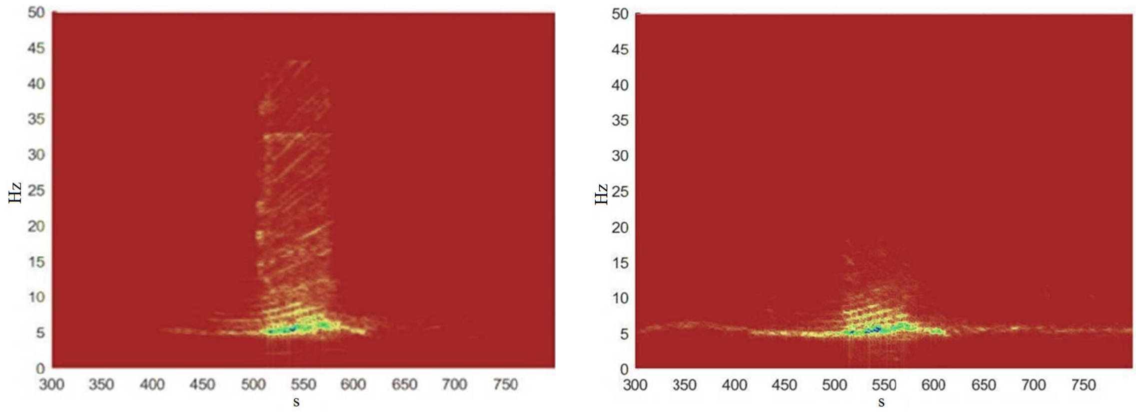
The presence of pulsations is associated with the phenomenon of multipath propagation of seismic vibrations, which entails interference of vibrations at points in space. In relation to the presented STF of seismic vibrations in the range of distances 450-1100 m, the attenuation of the spectral mode level is about 5-6 times. Another example in Fig. 1b illustrates the STF noise of a heavy truck KAMAZ, which is characterized by a spectral mode in the district of 43.7 Hz.

An example of obtaining and analyzing the SVF of railway transport noises –passenger train noises-is shown in Fig. 2: a) - seismic noise, b) - acoustic noise. In this case, seismic noise covers the frequency band of 5-40 Hz (Fig. 2a) with the location of the main spectral modes in the region of 8-9 Hz, 20 Hz. In relation to simultaneously recorded acoustic noise (Fig. 2b), it can be seen that the frequency range of noise is already in the range of 3-15 Hz, and the main mode of noise lies in the region of 7-8 Hz. For comparison, see Fig.3 shows the STF projections on the frequency-time plane for seismic and acoustic noise of a heavily loaded freight train. Here we can see that the prevailing frequency range of seismic (Fig. 3a) and acoustic (Fig. 3b) noise is shifted down in comparison with Fig.2, covering the frequency range of 4-10 Hz. In this case, the main spectral mode lies in the region of 6-7 Hz.



a) b)

Fig.2. Spectral-time functions (STF) and their projections on the "frequency-time" plane for passenger train noises a)-seismic; b) – acoustic.



a) b)

Fig.3. STF projections on the "frequency-time" plane of noise of a heavily loaded freight train for: a)- seismic noise; b) - acoustic noise.

V. DISCUSSION OF RESULTS

The problem of harmful effects of man-made noise on the environment in the area of low and infra-low frequencies, the most environmentally dangerous for humans, as well as destructive for large structures (bridges, buildings, industrial premises, etc.) is considered. The method of spectral-time analysis is proposed and implemented real noise recordings of various types of heavy transport. The obtained statistics of the results prove the concentration of the prevailing levels of transport noise in environmentally dangerous frequency limits. Weather-dependent factors of increasing geo-ecological risks from noise for social infrastructure are analyzed.

As a result of the analysis, the possibility of multiple increases in environmental risks at low frequencies is shown.

VI. CONCLUSION

1. A complex theoretical and experimental approach is proposed and analyzed in order to solve the problem of reducing geo-ecological risks from man-made noise. Frequency analysis and estimation of the most harmful frequency components of noise from various types of heavy transport have been carried out. Theoretical and experimental assessment of geoecological risks under the influence of meteorological factors on the propagation of infrasound in the atmosphere has been carried out.

2. The work was performed in the interests of the critical technology of the Russian Federation for the prevention and elimination of natural and technogenic character.

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