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Methods and experience of monitoring and reduction of infrasound radiation in low emission zones of Russia

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Summary
Infrasound is one of the serious sources of discomfort in conditions of urban territories. Especially important is the problem of infrasound monitoring and reduction in control in low emissions zones due to significant negative impact. Main infrasound sources in towns are considered. Methods of infrasound monitoring and assessment in town conditions are analyzed. Peculiarities of infrasound assessment and measurements in low emissions zones of Russia are described. Results of noise measurements in the territory of towns of Samara Region of Russia are presented. It was shown that there are exists the zones of urban territories with increased infrasound levels, especially in dwelling territories situated near to automobile roads and large industrial enterprises. Approaches to infrasound reduction and examples of its realizations for the territory of Samara region are presented. Infrasound mapping approaches are suggested. Presently there are not exists generally accepted international methods of estimation of infrasound impact in towns. Therefore it is important task to improve the existing methods of infrasound estimation, monitoring and mapping. Basing on comparative analysis of existing Russian and European methods of infrasound monitoring and assessment, new improved integrating methods are suggested.

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1. Introduction

Negative impact of physical pollutions in towns is growing every year. Infrasound is one of the serious sources of discomfort in conditions of urban territories [1-9]. Infrasound causes significant negative impact on the human health, especially on vestibular apparatus, cardiovascular system and may also impact on the internal organs of man. In result of infrasound impact man may feel fear, earache, headache, imbalance.
Especially important is the problem of infrasound monitoring and reduction in control in low emissions zones due to significant negative impact.
Statistics of infrasound estimation in Russian towns shows that al least half of inhabitants of towns are presently affected by increased infrasound levels.
This paper is devoted to study of methods of monitoring and reduction of infrasound impact in low emission zones on the example of Samara Region of Russia.

2. Analysis of main infrasound sources in towns

Widely infrasound sources may be subdivided to the natural and artificial. Natural sources are sea waves wind turbulence, meteors, exploding volcanoes, earthquakes; artificial (man-caused) are low-rotated compressors, ventilation systems, nuclear and chemical explosions, transport, industrial plants etc.
Main sources of infrasound and low frequency sound of urban territories of Russia are:
• separate cars and other vehicles;
• automobile transport flows;
• railway transport;
• system of ventilation and conditioning;
• industrial enterprises, industrial and technological equipment;
• different constructions works;
• internal sources;
• transformer substations etc.
Degree of impact of above described sources is depend on the number of factors: mutual dislocation of sources and of residential development, intensity and kinds of transport flows

etc. It is necessary also to take into consideration some other sources of low frequency sound and infrasound for living areas: sport areas, cultural and entertainment facilities, waste-transportation machines etc.
In Russian towns main infrasound sources are transport flows and industrial enterprises. Transport number in towns is increasing with every month, and negative impact of infrasound from transport flows is constantly increasing.

3. Methods of infrasound monitoring and estimation in Russia

Main Russian normative document in which existing infrasound permissible values are determined in Sanitary norms SN 2.2.4./2.1.8.583-96. Physical factors environment: Infrasound on jobs, in residential and public premises and territory residential area. Russian Ministry of Health, Moscow, 1997. In this document normative parameters and admissible levels of infrasound are determined.

Table 1 – Maximum levels in linear dB admissible for infrasound according to Russian legislation [SN 2.2.4./2.1.8.583-96]

	Frequency					
Site	**2**	**4**	**8**	**16**	**Global**	**[Hz]**
Workers in the heavy industry sector	100	95	90	85	100	[dB Lin]
Workers who perform office activities	95	90	85	80	95	[dB Lin]
Inhabited areas	90	85	80	75	90	[dB Lin]
Residential Areas	75	70	65	60	75	[dB Lin]

Normative parameters are sound pressure levels (L_p) in octave bands with mean geometric frequences 2, 4, 8 and 16 HZ and sound pressure levels measured on the scale of sound pressure meter "Lin", dB Lin. For standardization of characteristic of fluctuating infrasound equivalent on energy sound pressure levels (L_{ecv}), dB, and equivalent total level of sound pressure, dB Lin are used.
Maximally admissible levels of infrasound in working places, different for the various works, and also admissible infrasound levels in living and public area and on the territory of residential development are shown in table 1.
It is evident that existing Russian methods of infrasound standardization are having significant disadvantages. One of them is that special restrictions for low emissions zones are not determined. So, it is necessary to improve the methods and documents and to integrate it with international requirements. It is necessary also to develop new equipment for infrasound monitoring, because existing equipment is not allowing to carry out infrasound monitoring for the all measurement conditions.
For estimation of propagation of environmental low frequency noise and infrasound it is necessary to modeling propagation in the open space. In fact it is difficult task due to the numerous acoustical effects like diffraction, refraction, reflections, superposition etc. That is why it is necessary to select appropriate methodical approaches for environmental low frequency noise and infrasound modeling. For example, concerning transport low frequency noise and infrasound evaluation it is better to model not noise of separate cars, but transport flow noise. Formalization and modeling of transport flows it is convenient to do by using of influence diagrams. Such diagrams are usually describing some formalized presentation of modeled categories (objects, processes, properties etc.) in a form of multitude of graphical symbols (assemblies, vertexes) and relations between it. In Russia the types of influence diagrams are the most popular to use in a form of flow graphs, trees of events and functional nets [4, 5]. Flow graphs are including the variety of vertexes and a set of regulated and of unregulated couples, using for visual presentation of modeling process.

4. Results of infrasound measurements on the territory of Samara region of Russia

Under supervision of author of paper infrasound levels on the territory of Samara region have been measured. Measurements were carried out by using of "Octava 101 AM" sound level meter and other equipment.

As a measuring parameters equivalent sound pressure levels (L_{ecv}), dB, equivalent total level of sound pressure, dB Lin, octave and 1/3 octave spectra of sound pressure (dB) were used. Measurements have carried out in day time in weekdays mainly in rush hours and in night time (since 23.00 till 7.00). Measured noise levels were evaluated according the requirements of Russian Sanitary Norms SN 2.2.4./2.1.8.583-96. Requirements of Russian Building Norms and Rules were also taken into consideration.

Results of measurements in every point have been presented as measurements registration forms, which including date, time and place of measurements carrying out, measuring points numbers and digital data of readings of infrasound levels in measured point, as well as in form of spectral presentation of infrasound pressure levels [1-3].

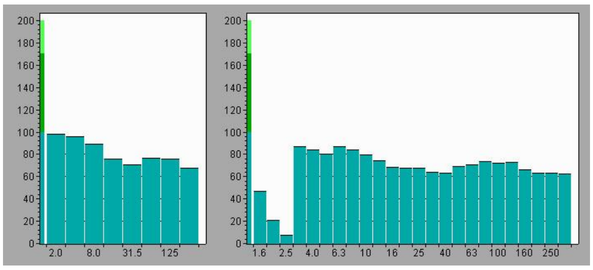

Figure 1. Spectral characteristic of infrasound levels for the point of measurements N 17, Octyabrsky district, Novo-Sadovaya Street, house N33 (octave and 1/3 octave ranges)

In Samara city noise levels were measured in some of the most important streets. The most significant exceeding values of sanitary norms requirements were obtained in point of measurement N7, Industrial district, living territory of Solnechniy-2 micro-district (on the frequency 2 Hz – exceeding is 1 dB, on the frequency 4 Hz – 3 dB, on the frequency 8 Hz – 3 dB, on the frequency 16 Hz – 7 dB), point N8, Industrial district, Novovokzalnyaya Street, house N162 (on the frequency 2 Hz – 2 dB, on the frequency 8 Hz – 13 dB), point N17, Octyabrsky district, Novo-Sadovaya Street, house N33 (on the frequency 2 Гц – 8 dB, on the frequency 4 Гц – 6 dB, on the frequency 8 Гц – 9 dB, on the frequency 16 Hz – 1 dB), point N19, Leninsky district, Samarskaya Street, house N270 (on the frequency 2 Hz – 8 dB, on the frequency 4 Hz – 4 dB, on the frequency 8 Hz – 2 dB, on the frequency 16 Hz – 1 dB) etc.

Example of presentation of infrasound spectral characteristic for the point of measurements N 17, Octyabrsky district, Novo-Sadovaya Street, house N33 is shown in figure 1.

For Togliatti city measurements of infrasound were carried out in more than 50 points of the living territory of the Avtozavodsky, Central and Komsomolsky districts near to the streets with intensive transport movement and near to industrial zones.

Example of presentation of infrasound spectral characteristic for the points of measurements N4 of Komsomolsky district, Makarova Street, 47 and N 15 of Komsomolsky district, Chaykinoy Street, 63 is shown in figures 2 and 3.

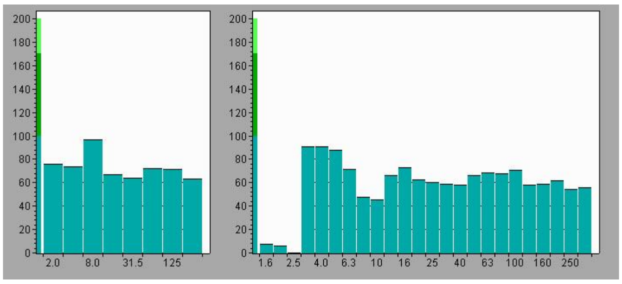

Figure 2. Spectral characteristic of infrasound levels for the point of measurements N 4 of Komsomolsky district, Makarova Street, 47 (octave and 1/3 octave ranges)

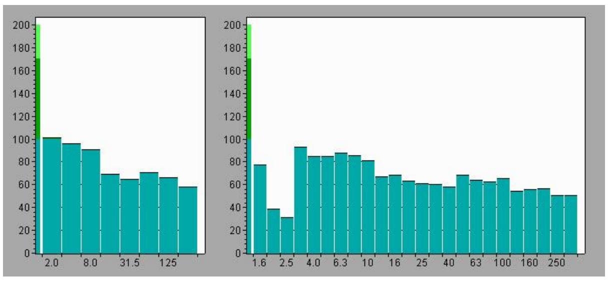

Figure 3. Spectral characteristic of infrasound levels for the point of measurements N 15 of Komsomolsky district, Chaykinoy Street, 63 (octave and 1/3 octave ranges)

It was determined exceeding of Russian sanitary norms for points of measurement N4, Makarova Street, 47; N5, Gidrotechnicheskaya Street, 23;

N6, Vokzalynaya Street, 25; 7, Kuibysheva Street, 30 etc.
Analysis of measurement results of infrasound levels in living territory of Samara region shows, that there are dangerous zones of dwelling territory. The most serious problem of infrasound influence is for the dwelling territories of Samara region adjoining to transport highways and to industrial enterprises.
Map of infrasound levels of the territory of Komsomolsky district of Togliatti city is shown in figure 4. Points of measurements with infrasound levels corresponding to the normative requirements, are shown in green color, and points with exceeding infrasound levels are shown in red color. As we may see, the most of points of measurements are having red color.

Figure 4. Map of infrasound levels of the territory of Komsomolsky district of Togliatti city

5. Reduction of infrasound in towns

Reduction of infrasound in urban territories up to admitted hygiene requirements is very serious and difficult task.
It is possible to point out some important approaches to infrasound reduction in the dwelling territories:
1. Infrasound reduction in the sources of generation: equipment of industrial enterprises, transport etc. For low frequency noise reduction active noise control methods are widely used now.
2. Administrative-organizing measures of infrasound reduction: decreasing of intensity of transport flows; improvement of roads quality, provision of rational velocity of movement; exclusion of automobile (especially lorry) transport traffic in central parts of town and in living area streets, restriction measures of high traffic movement near to the hospitals, schools etc.
3. Legal acts, technical norms, prohibitions of noise generation in living zones etc.
The most efficient measure is infrasound reduction in the source of its generation. Author have developed systematization of classification principles and types of classifications of the systems of active compensation of low frequency noise and infrasound [10]. Such classification principles are systematized as sphere of acting of active signal, directivity of sensors and emitters, type of cancelled and compensating signals, type of the space of compensation, field of application etc.
Possibilities of multifunctional application of systems of active and hybrid compensation of low frequency noise and infrasound were developed.
The main automobile external noise source is internal combustion engine (in low-frequency range mainly intake and exhaust aerodynamic radiation). Some compact and efficient constructions of active mufflers of intake and exhaust automobile engines noise reduction were developed by the author, [10]. Principal scheme of one of such constructions is shown in figure 5.

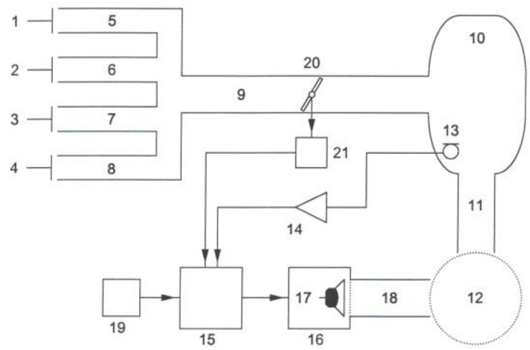

Figure 5. Principal scheme of low-frequency intake engine noise reduction by using of active muffle.

Some other measures of infrasound reduction should be used: rational organization of transport flows, prohibition of transport movement at some districts etc.

6. Conclusions

Main infrasound sources in towns are considered. Analysis shows that for the towns of Russia transport and industry are the main sources of infrasound of the living territories [5].
Methods of infrasound monitoring and assessment in town conditions are analyzed. It was shown that existing Russian methods of infrasound

standardization are having significant disadvantages. One of them is that special restrictions for low emissions zones are not determined. So, it is necessary to improve the methods and documents and to integrate it with international requirements.

Results of noise measurements in the territory of towns of Samara Region of Russia are presented. There are exists the zones of urban territories with increased infrasound levels, especially in dwelling territories situated near to automobile roads and large industrial enterprises.

Approaches to infrasound reduction for the territory of Samara region are discussed. The most efficient measure is infrasound reduction in the source of its generation.

Infrasound mapping approach is shown on the example of the territory of Komsomolsky district of Togliatti city.

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