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Main aspects of vibroacoustic factors assessment

N. Kh. Abdrakhmanov[1], A.V. Fedosov[1], A. N. Khamitova[1], I. I. Badrtdinova[1], G. L. Matuzov[2],

[1]Ufa State Petroleum Technical University (Ufa, Russian Federation)

[2]Bashkir State Medical University (Ufa, Russian Federation)

Introduction. In the age of automation and mechanization of labor, noise and vibration have become the leading dangerous and harmful production factors (DHPF) in various industries and agriculture. In order to reduce the harmful effects of vibroacoustic factors on the human body, first of all, it is necessary to evaluate this factor. The article provides general information on the assessment of working conditions under the influence of vibroacoustic factors.

Problem Statement. The aim of this work is to study the main aspects in the assessment of vibroacoustic factors.

Theoretical Part. As basic information, the paper provides the definitions of noise and vibration, their main characteristics, classification, hygienic regulation, the negative impact of these factors on human health, methods of assessment and measures of protection against them.

Conclusion. The study of the main aspects of the assessment of vibroacoustic factors allows us to analyze the DHPF and further develop measures to reduce the negative impact of these factors on the human body.

Keywords: noise, vibration, dangerous and harmful production factors, hygienic assessment.

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Introduction. Among the huge number of dangerous and harmful production factors that have a negative impact on human health, there are those that a human constantly faces: at work, on production sites, in transport and at home.

Such factors include vibroacoustic, containing vibration, noise, infrasound and ultrasound ones (Fig. 1). Vibroacoustic factors are considered one of the most common harmful and dangerous industrial factors and occupy a leading place among the causes of occupational diseases. They are called the "gray plague" of the XX and XXI centuries. It should be noted that these factors can be safely called relative to each other; they all have an oscillatory nature.

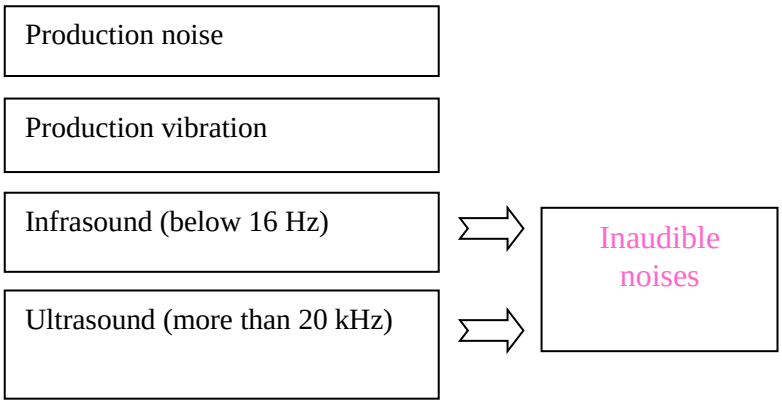


Fig. 1. Vibroacoustic factors

Problem Statement. The task of this work is to study the main aspects of the assessment of workplaces by vibroacoustic factors.

Theoretical Part. *Physical basis of noise level assessment*. From a physical point of view, noise is a chaotic combination of sounds with different intensity and frequency, which has an adverse effect on a person. In turn, sound is called the vibrational motion of particles of an elastic medium, which circulates in the form of waves in solid, liquid and gaseous media. Noise can also be defined as a sensation perceived by the hearing organs during the action of sound waves on them in the frequency range of 16-20,000 Hz.

Hygienic rating and classification of noise. Like any other harmful production factor, noise has a set of indicators by which it is evaluated. The main factors include:

— oscillation frequency (number of vibrations produced per unit time);

— sound intensity (the amount equal to the amount of energy transported by a sound wave through a unit area of the medium per unit time);

— sound pressure — difference between the pressure in the perturbed environment and the mean value of the atmospheric pressure (Fig. 2) [1].

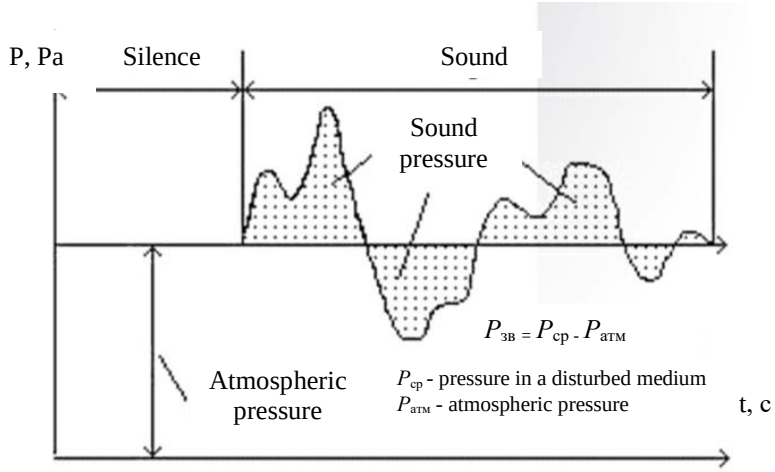


Fig. 2. Sound pressure

The sound intensity *(I, W/m²)* is determined by the formula

$$I = \frac{p^2}{\rho \times c} \quad (1)$$

where p — sound pressure, Pa;

ρ — density of the medium, kg/m^3;

c — sound speed, m/s.

Between the threshold of audibility and the pain threshold is the area of auditory perception, which includes 14 orders of magnitude (Fig. 3). However, with the use of the absolute values of these indicators, it is impossible to draw a conclusion about the working condition in the interval of an 8-hour working shift, so a logarithmic scale is used (the entire area of physical characteristics of sound pressures and intensities is recorded not by multi-digit numbers of absolute values, but by logarithms of the ratios of these values to values equal to the threshold of audibility).

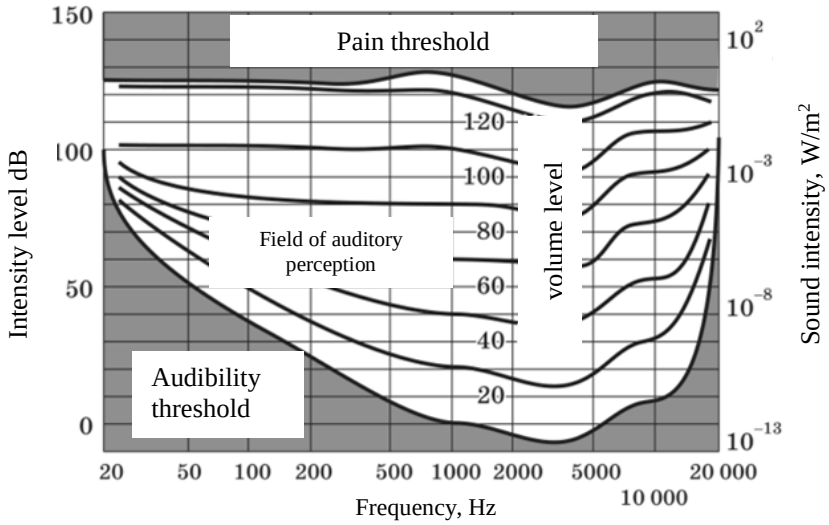


Fig. 3. Audibility diagram for the human ear

In the process of hygienic assessment of working conditions, the entire frequency range is divided into bands of a certain width (spectra).

Octave is a spectrum of frequencies where the ratio of the upper frequency to the lower is two. A third of an octave is a band of a certain frequency width, in which the ratio of the upper frequency to the lower is equal to the cubic root of two [2].

There are a large number of classification features by which noise is distinguished (Table 1).

Table 1

Noise classification

<table>
<tr><th>By the source of occurrence</th><th>By frequency</th><th>By spectrum</th><th colspan="3">By time</th><th>By color</th></tr>
<tr><td>Mechanical</td><td>Low-frequency – up to 300 Hz</td><td>Wide-band</td><td colspan="3">Constan</td><td>White</td></tr>
<tr><td rowspan="2">Aero -, hydro-dynamic</td><td rowspan="2">Midrange-from 300 to 800 Hz</td><td rowspan="3">Tonal</td><td colspan="3">Non-constant</td><td>Gray</td></tr>
<tr><td rowspan="2">Oscillating</td><td rowspan="2">Intermittent</td><td rowspan="2">Pulse</td><td rowspan="2">Pink</td></tr>
<tr><td>Electrodynamic</td><td>High-frequency – more than 800 Hz</td><td>Other</td></tr>
</table>

However, the most significant value in working conditions assessment is given to the classification on a temporary basis, in which noise can be divided into constant (the sound level changes by no more than 5 dBA) and non-constant (the sound level changes by more than 5 dBA).

The normalized parameter of constant noise is the sound pressure level; it is measured in 9 octave bands with corresponding geometric mean frequencies. The equivalent (in terms of energy) sound level is a normalized parameter of non-constant noise (Fig. 4) [3].

Constant

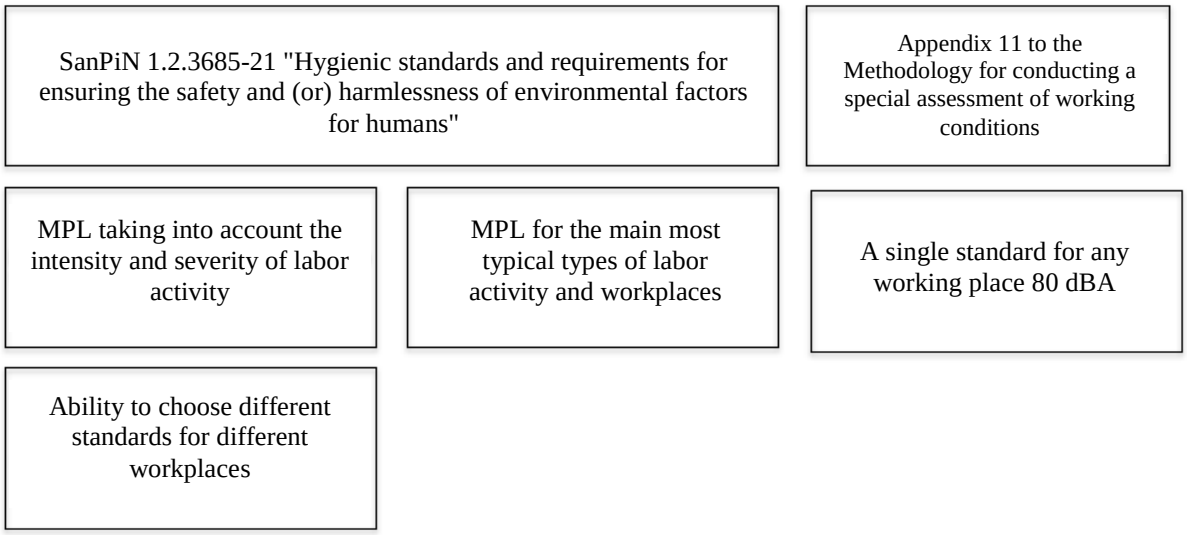
- Sound pressure levels L (dB), in octave frequency bands with average geometric frequencies 31,5; 63; 125; 250; 500; 1000; 2000; 4000 and 8000 Hz

Non-constant

- Equivalent (in terms of energy) sound level, (dBA), in octave frequency bands with average geometric frequencies 31,5; 63; 125; 250; 500; 1000; 2000; 4000 and 8000 Hz

Fig. 4. Noise rating

It can be noted that for two procedures in the field of working conditions assessment, i.e. for production control and special assessment of working conditions (SAWC), the approaches to noise levels rating differ. So, for a special assessment, a single standard was adopted — 80 dBA, and there is a choice for production control (Fig. 5).



In addition, noise rating depends on the intensity and severity of the labor process (Fig. 6).

Category of intensity of the labor process	Category of severity of the labor process				
	Light physical activity	Average physical activity	Light physical activity		
			1st degree	2st degree	3st degree
Mild intensity	80	80	75	75	75
Moderate intensity	70	70	65	65	65
Intense work of the 1st degree	60	60			
Intense work of the 2st degree	50	50			

Fig. 6. Noise rating depending on the severity and intensity of labor

A possible reason for the differences in the regulation of noise levels within the framework of production control and special assessment of working conditions, according to the authors, is the state policy in the field of assessment of working conditions aimed at reducing jobs with harmful working conditions.

The effect of noise on the body. Noise negatively affects the entire human body, but to a greater extent the organ of hearing and the central nervous system. The effect of noise is characterized by an accumulating effect, which leads to the emergence of an occupational disease — sensorineural hearing loss (Fig. 7) [4].

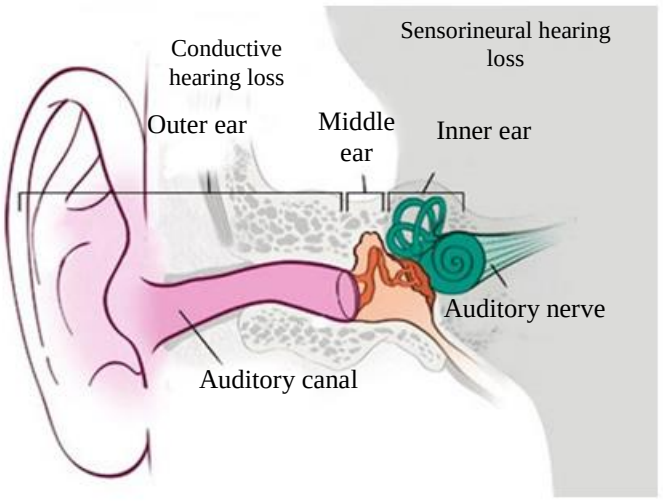


Fig. 7. The effect of noise on the human organ of hearing

Noise protection. Personal hearing protection equipment includes headphones, anti-noise helmets, earplugs. Collective noise protection measures are divided into two types:

— means that reduce noise at the source of occurrence (changes in the design of equipment, the use of technological processes and equipment that do not emit strong noise);

— means that reduce noise in the propagation path (sound insulation).

With the use of sound absorption, you can reduce noise by only 5-10 dB and with the help of sound insulation — by 30-70 dB.

Measuring instruments. Noise in the workplace is measured using noise meters or noise dosimeters. The most widely used models of noise meters are SVAN and OCTAVE (Fig. 8) [5].

Noise meters SVAN 943A **OCTAVE-110A**

Fig. 8. Noise meters

Physical basis for vibration levels assessment. Vibration is an oscillatory process in mechanical systems, in which a material body after a certain period of time comes to the same stable position. The causes of vibration excitation are unbalanced force effects (reciprocating, rotating, impacts of parts).

Hygienic rating and classification of vibration. Like any other harmful production factor, vibration has a set of indicators by which it is assessed. The main indicators include the amplitude of vibration displacement, the frequency of vibrations, mechanical impedance, vibration velocity and vibration acceleration.

By analogy with noise, a logarithmic scale is used to assess working conditions by vibration (the entire range of vibration speeds and vibration accelerations is recorded not by multi-digit numbers of their absolute values, but by logarithms of the ratios of these values to the corresponding threshold values) [6].

The vibration velocity level *(L_v, dB)* is calculated by the formula

$$L_V = 10lg \times \left(\frac{V^2}{V_0^2}\right) = 20lg \times \left(\frac{V}{V_0}\right), \quad (2)$$

where V – vibration velocity value, m/s;

$V_0=5\cdot10^{-8}$ m/s – speed threshold value.

Vibration acceleration level *(L_a, dB)* is calculated by the formula

$$L_a = 20lg \times \left(\frac{a}{a_0}\right), \quad (3)$$

where a – acceleration value, m/s^2;$a_0=1*10^{-6}$м/с^2 – пороговое значение ускорения.

There are a huge number of classification features by which vibrations are distinguished: by source, by direction of action, by type of source, by time, by method of the influence on a person (Fig. 9).

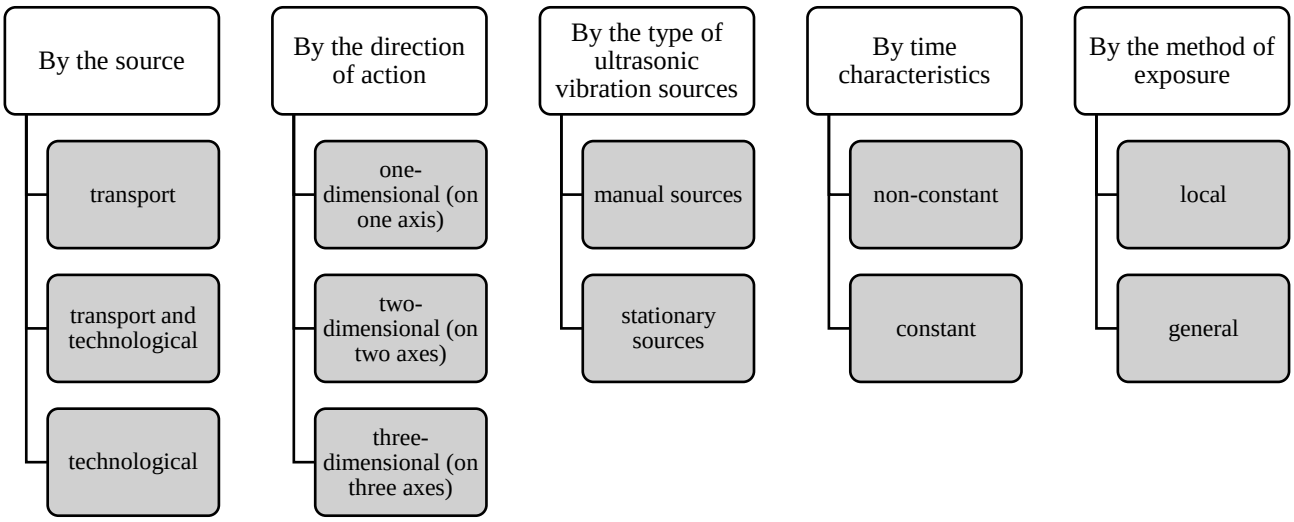


Fig. 9. Classification of vibration

But the most important thing for working conditions assessment is a temporary sign, according to which vibration is divided into constant and non-constant. In turn, non-constant vibration is divided into intermittent, oscillating and pulsed [7].

It should also be added that vibration according to the method of exposure to a person is classified as general and local (Fig. 10). Due to the fact that local vibration has a wider frequency range, it is considered more harmful than the general one.

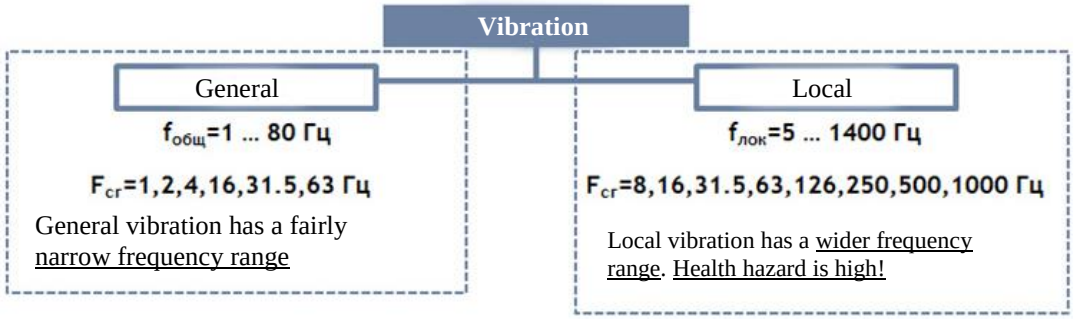


Fig. 10. Frequency characteristics of vibration

Depending on the type of vibration (general or local, constant or non-constant), it is rated. The rate parameter of constant vibration is the corrected level of vibration acceleration, and of the non-constant one is the equivalent corrected level of vibration acceleration.

It should be noted that for two procedures in the field of working conditions assessment, that is, for production control and special assessment of working conditions, the approaches to vibration rating differ. Thus, uniform standards

have been adopted for a special assessment, and there is a choice for production control depending on the source of vibration (Table 2).

Table 2

Vibration regulation in production control and special assessment of working conditions

Production control Manual 2.2.2006-05	Special assessment of working conditions
Local vibration Use of weighting coefficients for frequency bands, use of AEL for frequency bands	Local vibration Use of AEL for frequency bands
General vibration Use of weighting factors for frequency bands Use of AEL for several categories (according to the source)	General vibration No divisiion by the source Use of AEL for setting the TUA on the Z axis and on the X, Y axes in dB

According to the authors, a possible reason for the differences in the regulation of vibration in the framework of production control and special assessment of working conditions is the state policy in the field of working conditions assessment aimed at reducing jobs with harmful working conditions.

Vibration measurements at the workplace are performed using vibrometers. The most widely used models of vibrometers are SVAN and OCTAVE (Fig. 11) [8].

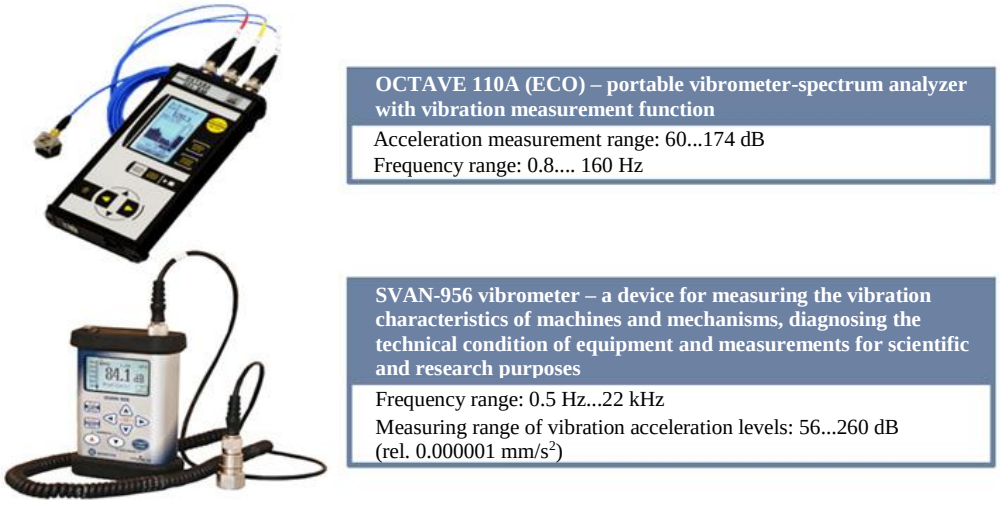


Fig. 11. Measurement of vibration parameters

The effect of vibration on the body. The impact of vibration on a person is much more complex than that of noise, but it also has a greater negative impact on the nervous system.

An occupational disease caused by exposure to vibration is called vibration disease or "white fingers disease". There are three stages of vibration disease.

At the first stage, there is a violation of skin sensitivity; there is pain and weakness in the hands. The second stage is accompanied by the processes of bringing the fingers together, changing the color of the skin. During the third stage, irreversible changes occur in the cardiovascular and central nervous system, atrophy of the limbs occurs (Fig. 12) [9].

Fig. 12. Vibration disease

The most common diseases are caused by local vibration; it can cause a slowdown in blood circulation in the hands, fingers, forearms, heart vessels. Vibration, which transmits vibrations from the legs to the head, is particularly adversely affected.

Means of protection against vibration. The means of protection against vibration include reducing vibration in its source, reducing vibration on the path of propagation, organizational, technical and therapeutic and preventive measures, use of personal protective equipment (vibration-insulating shoes, soles, special insoles, gaskets, liners, specialized mittens and gloves).

Vibration measurement tools. Vibration can be measured using vibrometers and vibration analyzers.

Vibrometer is a device for measuring vibration velocity. Modern vibrometers, in addition to measuring vibration, determine additional parameters. For example, the Fluke 805 vibrometer also measures the temperature of bearings (Fig. 13).

Fig. 13. Fluke Vibrometer

A vibration analyzer is a more complex measuring device compared to a vibrometer (Fig. 14). Unlike a vibrometer, a vibration analyzer allows you to track vibration in dynamics, that is, with the help of a vibrometer, you can measure vibration at a specific time, and with the help of an analyzer, you can estimate the change in this parameter [10].

Fig. 14. Vibration analyzer

There are many professions that are characterized by exceeding the hygienic standards for vibroacoustic factors. An example of such a profession is the driver of a compressor unit, the noise level of which can reach 100 decibels at a rate of eighty. Accordingly, the class of working conditions at such a workplace will be 3.1 and higher, which determines the need to develop measures to improve working conditions.

Conclusion. The authors of the article conducted a study of the main aspects of the assessment of vibroacoustic factors. This assessment allows you to analyze dangerous and harmful production factors and further develop measures to reduce their negative impact on the human body.

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About the authors:

Abdrakhmanov, Nail Kh., Head, Department of Industrial Safety and Labor Protection, Ufa State Petroleum Technical University (4, Matvey Pinsky str., Ufa, RF, 450044), Dr. Sci., Professor, ORCID: https://orcid.org/0000-0002-3184-1975, anailx@mail.ru

Fedosov, Artem V., Associate professor, Department of Industrial Safety and Labor Protection, Ufa State Petroleum Technical University (4, Matvey Pinsky str., Ufa, RF, 450044), PhD, ORCID: https://orcid.org/0000-0002-7853-1800, fedsv-artem@rambler.ru

Khamitova, Alina N., Master's degree student, Department of Industrial Safety and Labor Protection, Ufa State Petroleum Technical University (4, Matvey Pinsky str., Ufa, RF, 450044), ORCID: https://orcid.org/0000-0001-8442-9418, khamitova.alya@mail.ru

Badrtdinova, Ilzida I., Master's degree student, Department of Industrial Safety and Labor Protection, Ufa State Petroleum Technical University (4, Matvey Pinsky str., Ufa, RF, 450044), ORCID: https://orcid.org/0000-0001-7901-7355, b.ilzida99@mail.ru

Matuzov, Gleb L., Associate professor, Department of Mobilization Training in Health Care and Disaster Medicine, Bashkir State Medical University (3, Lenina str., Ufa, RF, 450008), Cand.Sci., ORCID: https://orcid.org/0000-0003-2619-4184, gleb-matuzov@yandex.ru

Contribution of the authors:

N. H. Abdrakhmanov — structure of the article, critical analysis, editing; A. V. Fedosov — scientific supervision, formulation of the main objectives of the study, the method of its carrying out, processing of observational data, text editing; A. N. Khamitova — problem statement, formulation of basic concepts of the study, formulation of the conclusions; I. I. Badrtdinova — completion of the text, collection and analysis of the literature data; G. L. Matuzov — development of the concept of the study, data processing observations.