METHODOLOGICAL APPROACHES FOR THE PREVENTION OF COMBINED EFFECTS OF NOISE AND VIBRATION ON THE BODY

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In experimental conditions conducted the estimation of the combined action of noise and vibration on an organism of examinees. During experiment it has been revealed that indicators reflecting a condition of the central nervous system and the higher nervous activity, acoustical and vibrating sensitivity had considerable deviations even at action of factors at level of the sanitary standards and exceed such standards in the separate action of both factors, indicating that the adverse effects of two factors at their combined effect.

Keywords: methodological approaches, combined effect, noise, vibration

A major focus of preventive medicine, which aims at optimizing the working conditions, and reduction of morbidity and improvement the workers health is the hygienic regulation of parameters of adverse factors of production environment. In this regard, developing a framework of hygienic standardization of noise and vibration should be considered as absolute achievement in medical science (Suvorov G.A., Ovakimov V.D. et al, 1990). So, lately, one of the main tasks of hygienic science in regulation is a matter of choice and justification of the criteria that adequately reflect the degree of influence of production noise and vibration of various kinds on the organisms of the workers. With their help it would be possible to estimate the probability of noise-vibration pathology simultaneously on all three physical parameters that characterize their impact – the level, composition, frequency fluctuations and exposure time (Tatkeyev T.A., 1999, 2005).

Approaches to different hygienic evaluation (frequency, level and duration of exposure) of noise and vibration made it possible to determine the theoretical concept of the energy impact of noise and vibration. In accordance with the energy model of non-permanent noise and vibration action their hygienic assessment is equivalent (in energy) to the level of sound or vibration, which is an integral over time in the sound level in dB A or adjust the value of vibration in the DB (Suvorov G.A., 1991). Energy model of noise and vibration action has been confirmed in studies and was implemented in the development of modern principles of rationing (Abullin Kh.A., Amangeldin S.K., 2001). The necessity for normalization of vibration and noise in their combined effect on the human body was proved. This is due to the fact that both factors usually accompany each other in the production environment. The data of domestic and foreign literature suggests that the combined effect of vibration and noise causes more expressed functional changes in human bodies compared to the separate influence of these factors at the same levels (Kulkybayev G.A., Tatkeyev T.A., 2002, Tatkeyev T.A., Tekebayev K.O., 1999).

The aim of the work was to develop a new methodological approach to the study of the quantitative evaluation of the organism reactions to the combined impact of noise and vibration factors.

Materials and methods of research

In accordance with the assigned tasks we carried out production and experimental research. Production studies were carried out at Zhayrem mining processing plant. Experimental studies were conducted in the laboratory of Industrial Hygiene (National Centre of Labour Hygiene and Occupational Diseases MH Kazakhstan, Karaganda).

Hygienic studies included measurement of levels of vibration, noise at the drills operators' workplaces and timing observations. Measurement of noise and vibration was conducted on the vibroacoustic equipment of the company «SVAN» (Russia).

Measurements of noise in the workplaces were carried out while performance of the basic technological operations taking into account the requirements. Measurements were made with a triple recurrence. Noise parameters were evaluated by sound pressure level in octave bands with subsequent calculation of the dose of noise. Vibration parameters were studied by the levels of the mean values of the vibration velocity in octave frequency bands with subsequent calculation of adjusted equivalent dose levels and vibration. We determined the structure of work activities including working process evaluation by operations, their change and duration, timing of the allocation of vibration exposure, work and leisure intervals' distribution, as well as presence of pauses and micropauses. Experiments were carried out in accordance with the principles of the mathematical theory of experiment involving 30 healthy volunteers (men), divided into three age groups of 18-31, 32-45, 46-59 years old, according to the scheme of a full two- factors experiment.

The loads were modeled with time exposure factors in the experimental chamber. Local vibration in the vertical direction with the main frequency of 31,5 Hz was reproduced on the vibrobench VSL-70/200. Using the broadband noise generator noise typical for drillers' work was reproduced. The lower, main and upper levels of the investigated effects were respectively 79, 85, 91 dB (at vibration accelerations) for the local vibration, 83, 89, 95 dB A for noise. Recalculated for an eight-hour work-

ing day, using the basic approach of dose levels of the studied noise and vibration loads were equivalent to the maximum permissible level, and upper and lower levels were 6 dB more and less than the standard. The plan of the experiment allowed to obtain independent estimates of linear effects of the isolated impact of each factor on the basis of four different combinations of upper and lower levels of the factors. For the experimental verification of the assumptions about the insignificance of the quadratic effects the 5-th version of the exposure was investigated when both factors were fixed at the basic levels.

Physiological studies included methods adequately reflecting the impact of noise and vibration on the sensitive areas: peripheral vascular, nervous and muscular systems. To assess the degree of change in sensitive areas we defined temporary threshold shift (TTS) and permanent threshold shift (PTS) of auditory and vibration sensitivity.

The most appropriate (specific) indicator for the vibration tension is the vibration sensitivity. This method is used to detect early signs of adverse effects of vibration. In our studies we used vibrotester «IVCH – 2». Thresholds of vibration sensitivity were measured on the phalanx of the right hand's third finger in the octave band of 125 Hz. Sensitivity threshold was recorded by 2-3 measurements, from the increase in signal to the sensitivity threshold, and gradual reduction from the above-threshold to imperceptible. Also the recovery period was taken into consideration.

Assessment of auditory function of the patients was performed in the frequency range of 125-8000 Hz. Measuring the auditive acuity in volunteers was conducted from sub-threshold to threshold intensity to exclude the influence of the residual sound image in a special chamber insulated from noise with a volume of 25 m and coefficient of sound insulation for more than 30 dBA. In audiometric studies the following indicators of auditory threshold sensitivity were taken as the leading ones in assessing auditory function: in the field of the speech frequencies (1000.2000 Hz), and loss of hearing at 4000, and 8000 Hz. The criterion for establishing temporary reduction of the hearing threshold, characterized as distressing (adverse) impact was accepted the rate of the arithmetic mean of reducing the threshold of hearing in the speech range, equal to 10 dB or more, time for «backward» adaptation, and temporary reduction of auditory threshold to its original values.

To determine the functional state of the central nervous system and visual analyzer of the patients we determined the duration of the latent period of the rate of hearing and sensomotor reactions to simple light, sound, and differentiated light stimuli. Time of reflex refers to the simplest form of reaction, but at the same time the visual and auditory analyzers have a great potential. Therefore, the changes occurring in the cortical link of the analyzers to a large extent reflect the degree of fatigue. Reaction time to light and sound depends on the speed of transmission of excitation through the central masses. Therefore, the reaction time to light and sound are widely used to assess the state of the central nervous system. To determine the time of the sensomotor reactions to light and sound (latent period of visual motor reactions (LP VMR), latent period of auditory motor reactions (LP AMR)) we used a hardware-software complex for psychophysiological research. This program presents various options of complexity with the issuance of the final result as a statistical report with the calculation of mathematical expectancy, average error, sigma, coefficient of variation, as well as the number of error decisions and the number of missed transactions. The program also gives the result as an entry in the file that allows to optimize the problem of collecting and processing the results.

Results of research and their discussion

In the two factors experiment with the participation of the volunteers in three age groups the effects of noise and local vibration in five different combinations to the change of the physiological characteristics of different body systems were studied. However, for greater objectivity we selected practically healthy people having no contact with the noise and vibration excessing maximum allowable levels to participate in the experiment.

Data on experimental studies of physiological functions indicated change in indicators of the functional status of the volunteers' organisms of varying severity depending on the dose of acoustic and mechanical vibrations, as well as on the age.

In the first age group of the volunteers action of the factors with doses equal to 25% of the permissible level did not cause significant changes of physiological parameters, and subjective feelings were comparable with those in their optimal levels (series I). In series II the action of the noise with the lower limit and action of the local vibration with the upper limit (91 dB) caused a significant decrease in the vibration frequency of the volunteers to 14,5 dB. The threshold of hearing at the frequency of 1000 Hz slightly increased compared with the control. Lowering the reaction time to light was 18,8; 13,0% to the sound, and differentiated response to the lowering of the leading lights of the latent period was 20,0%. Also in this series, we observed decrease in frequency of the pulse rate to 12,8%, decrease of the muscle strength to 12,4% compared with the control. According to the results of subjective sensations we traced significant decrease in the activity by 12% from the control.

A combination of factors with an upper level (95 dB A) of variation of noise and lower value of the vibration (series III) with an hour exposure was revealed in a significant increase in hearing threshold at 111,3% of the 1 kHz tone, a decrease in the rate of reaction to light and sound stimuli, respectively, to 16,5 and 20%, increase in the number of errors and reaction time for AVMR to 16,3%. The health reduction was 11,2%, mood decreased to 9,8% from the basic indicators. The most apparent changes in the volunteers' organisms in this age group were found in series IV, where both controlled factor took upper levels of variation and thus, were 4 times higher than the permissible dose. So the raising of the vibration frequency threshold to control was 97,1%, the threshold of hearing to the different tones rose in average

to 122,0–200,0% compared with the control. Increase of reaction time to light and sound was 22,0% and 22.3% respectively, relative to control. FFF decreased to 17,4%, decrease in frequency of the pulse rate was 14,0%, muscle strength decreased as compared with the control to 19,6%. There was a significant decrease in indices of subjective feeling of health, activity and mood to 14,3; 16,9 and 12.3% respectively.

In the series V of the experiments under the combined effects of noise and local vibration to levels equal to Sanitary Standards (SS) there was a significant increase in the threshold of the vibration sensitivity to 74,2%, increase in hearing threshold for speech and high tones at an average to 93,0–140,0%. The latent period of auditory motor reactions (AMR), visual motor reactions (VMR) and auditory-visual motor reactions (AVMR) increased to 14,2; 14,6 and 1,8% respectively. Decrease in frequency of the pulse rate was 7,9% compared with the control, and activity lowered to 10,7%, health feeling to 8,2%, and mood to 7,0%. In conducting parallel series of the experiments on the volunteers of the second age group we found the impact of the level was lower four times than the sanitary standards (SS). Series I did not cause significant changes of physiological parameters.

In the action of the noise level 4 times below SS and local vibration 4 times higher than SS (II series), we observed significant changes of vibration sensitivity, which decreased compared with the control to 74,5%. Also in this series we have recorded 30% increase in hearing threshold to tone I kHz as compared to the baseline. Increased reaction time to light and sound stimuli relative to control was 14,4% and 10,4% respectively. The response time for complex visual-motor reaction is also lengthened to 13,7% from the original. With the given parameters of physical factors the pulse reacted by curtailment to 9,5%, and muscle strength decreased to 11,0% from the control level. We observed decrease in activity to 10,3% according to the indicators of the subjective symptoms.

In Series III of the experiment after exposure to high noise and low vibration a significant increase in hearing threshold to 50,0–77,0% was observed, lowering of the vibration sensitivity amounted to 36,0% from the baseline level. Extending the reaction time to light, sound and differential stimuli was 12,5; 14,5% and 16,2% respectively. Decrease in frequency of the pulse to the frequency was 4,0%, and there was the falling rate of health to 10,2%, and the mood to 9,2% as compared with the control.

Under the influence of the factors with the levels exceeding SS (series VI), vibration sensitivity decreased as compared with the control to 81,0%, there was the increase of the hearing threshold to 58,0–80,0%. In the speech and high frequencies reaction time to light lengthened to 18,8%, sound to 24,2% and Differentiated auditory motor reactions time was 25,0% longer than the baseline level. Indicators of FFF decreased to 12,9%, and from the side of the cardiovascular system there was a decrease in frequency of the pulse to 12,0% compared with the control. Muscle strength decreased to 13,7%, and there was a decrease in feeling and mood to 13,6 and 12,5% respectively.

In the fifth series of the experiment index of vibration sensitivity decreased compared to the control to 54%, raising of the hearing threshold at frequencies was 43,0–56,0% compared with the control, reduction of reaction time to light was 11,6%, to the sound – 11,5% and differentiated auditory motor reactions – 12,3% compared with the baseline. The frequency of the pulse slowed to 6,3%. After the combined effect of the studied factors, in the third age group, we observed the following changes: in the series I there was a reliable reduction of vibration sensitivity to 30,9% of the initial value; in the series II, after exposure, there was a reduction of vibration sensitivity to 66%, time for auditory motor reactions decreased to 12,8%, time for visual motor reactions decreased to 22,2%, differentiated visual motor reactions and the number of errors increased to 20,2%. The pulse rate decreased to 11,6% from the baseline level, against this background muscle strength decreased to 20,5%. According to the indicators of the subjective lowering we found that health and activity decreased to 13,3 and 17,2% respectively.

Series III showed that after the exposure to noise 4 times exceeding SS level and 4 times exceeding the level of local vibration there was a significant lowering of the threshold of hearing to 12,0 dB. The vibration sensitivity decreased to 6 dB compared with the control. Time of visual motor reactions decreased from baseline to 16,7%, auditory motor reactions also decreased to 20,7%, and differentiated visual motor reactions decreased to 23,8% compared with the control. While the action of the factors specified levels FFF decreased to 20,3%.

In the experiment with the highest levels of noise and vibration (series IV), the deviations of the studied physiological parameters in comparison with other series were most significant. This increase in thresholds for vibration sensitivity was 16 dB relative to control, hearing thresholds also increased to 14 dB, deviations of visual motor reactions downward were 23,1%, while auditory motor reactions decreased to 30,5% and the time of auditory visual motor reactions fell to 26,0% compared with the control. We also noted the decrease of

FFF to 22,6%, decrease in frequency of heart rate was 14,3% in relation to the original level. The index of the muscle strength decreased to 26,3% of the control level. Here, we observed a significant, compared with other series decrease of subjective feelings, activity and mood to 19,1; 22,8 and 20,0% respectively.

By the combined effect of noise and local vibration with levels equal to SS (series V) we observed a significant increase in vibration sensitivity to 11,5 dB compared to the baseline level, while the hearing threshold increased to 9 dB compared to the control, decrease of the rate of reaction to light and sound were 17,2 and 19,7% respectively. Time for differentiated visual motor reactions increased compared with the control to 16,1%. FFF decreased to 8,9%, decrease in frequency of the pulse rate was 12,2% of the control, reduction of muscle strength was 14,6% of the baseline level. Feeling, activity and mood decreased to 11,3; 12,3 and 12,9 of the control.

For all the studied parameters, with the combined effects of different levels of variation factors of noise and local vibration we can see that the most expressed reaction were in the third age group. Also, it is clear that the greatest deviations of the functional systems of the body were observed in series 5 of the experiments under the influence of both factors in excess of health standards by 4 times. Under the action of both factors on the SS level (5 series), the deviations of physiological variables are less than in the series 2 and 3, in which one of the factors exceeds SS more than 4 times.

Thus, summarizing the results of five series of experiments with different combinations of noise and local vibration we can say that the controlled real doses in experiments of physical factors in the interaction with each other have a significant impact on the physiological functions of the body and subjective perceptions of the people with different strength of influence. In this case, as shown by analysis of the data, changes in the specific receptor systems (auditory and vibration sensitivity) mostly reflected the influence of adequate stimuli. The experiment revealed that the indicators reflecting the state of the central nervous system and higher nervous activity, acoustic and vibration sensitivity had significant deviations even under the influence of factors on the level of health standards and exceeded those in the separate action of both factors, indicating the adverse effect of two factors in their combined influence. This suggests the need to amend the existing regulations of noise and local vibration with regard to their combined effect on the workers' bodies as well as individual factors: individual sensitivity, congenital or acquired risk factors, harmful habbits and lifestyle factors.

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