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JUSTIFICATION OF ACCEPTABLE WORKING HOURS IN UNDERGROUND MINING

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The article presents justification of an acceptable length of shift and rest periods for employees engaged in underground mining works, namely extraction of potash ore. One of the main factors in determining the working hours and duration of exposure of employees to hazardous working conditions is individual adaptive abilities. The indicators of the cognitive functions of employees assessed with the help of neuropsychological tests served as markers for the assessment of the central nervous system; hemodynamics indicators served as the markers for the assessment of the circulatory system. Based on a comprehensive assessment of the central nervous system (autonomic division) and the circulatory system using the marker function parameters, the authors justified a possible length of a working day (shift) and respective working hours and rest periods for the employees engaged in underground mining works for the extraction of potash ore.

Keywords: *working hours, adaptation, functional disorders, underground mining*

Introduction. Under Article 94 of the RF Labor Code, the maximum length of a working day (shift) of employees involved in hazardous and (or) dangerous operations which have reduced working hours cannot exceed 8 hours, with a 36-hour working week. At the same time, industrial and intersectoral agreements and a solidarity contract can extend the maximum permissible length of a working day (shift) for employees involved in hazardous and (or) dangerous operations provided a prior written agreement of the employee and compliance with the maximum daily working hours. Labor conditions of employees involved in mining works at potash ore extracting enterprises fall under this category.

The labor of employees involved in potash ore extraction is cyclical and technologically complicated; it involves operations with various levels of mechanization, and uneven distribution of time spent on each operation during a shift.

Production process requires an ability to switch between production operations and techniques. When at work, the functional condition of an employee experiences changes. Maintaining productive (efficient) labor performance with a minimum use of functional reserves is the main factor underlying the determination of a work and rest schedule.

It is not possible to schedule shifts and rest period without taking into account the performance ability of an employee and need for rest during certain parts of a work day. During a work day,

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performance capability, or ability of an employee to perform a job, and correspondingly, the functional condition of an employee's body, undergoes changes. The main health risk factor associated with intense labor is weaker adaptation capabilities of an employee which can be detected long before first symptoms of a disease. Prediction and prevention of occupational diseases are an issue of current interest [7, 8].

It was determined that the change in the labor stereotype of an employee resulting from working in shifts does not involve full readjustment of the physiological functions. The main factor associated with longer working hours, different length of shifts and rest periods resulting in permanent functional disorders is overwork syndrome which causes uncontrolled fatigue [6].

Neurophysiological indicators show the final adaptation result i.e. an employee's ability to adapt to the major production and labor risk factors [5].

Employee's adaptation capabilities are a reserve that is spent on maintaining a balance between the body and the production environment; they should be considered as a limiting factor when developing a work schedule [2, 3].

The purpose of this study is to assess various working schedules that vary in terms of length of shifts and rest breaks (shifts = 8, 10, and 12 hours).

Research materials and methods.

In our study, we used the following groups of mining employees:

- A group of miners working 10-hours shifts - 56 employees, including operators of mining excavation machines – 47, mine foremen – 7, timberers - 2;

- A group of miners working 11-hours shifts - 70 employees, including operators of mining excavation machines – 60, mine foremen – 9, timberers - 2;

- A group of miners working 12-hour shifts - 65 employees, including operators of mining excavation machines – 51, mine foremen – 13, timberers - 1;

The groups were homogenous in terms of age and length of employment.

A diagnostic study was performed subject to the ethical standards set forth in a reviewed version of the Declaration of Helsinki adopted at the 59the WMA General Assembly in 2008. The employees included in the study groups were informed about the goals and objectives of the study, possible health risks, and the program and procedure of the medical studies of the functional parameters, and then signed a written consent to participate in the medical studies.

The impact of combined hazardous industrial factors was assessed with the help of compensatory-adaptive reactions of the main body systems (central nervous system and blood circulatory system) and identified via testing of a number of functional parameters – markers for the above systems.

The indicators of cognitive functions in employees assessed with the help of neuropsychological tests were used as the functional parameters – markers of the performance of central nervous system. The tests were selected based on the hypothesis on the mechanism behind the impairment of cognitive functions, general physical and mental state, and performance ability.

Cognitive functions in employees were assessed with the help of:

- a model chart including: patterned interview using a pre-prepared survey; the five-word test (B. Dubois) for the assessment of perception (immediate free recall); clock drawing test; repeated five-word test (delayed recall); a special table with random numbers from 1 to 25 (Schulte test); concentration test (serial counting); surveys:

- WAM (wellbeing, activity, mood) – helps evaluate productive capacity and detect signs of fatigue, subjective sleep analysis, evaluation of wellbeing, activity, and mood.

Subjective sleep analysis is performed to assess productive capacity and detect signs of fatigue.

The following indicators were used as functional parameters – markers for the assessment of the circulatory system:

- Measurement of blood pressure and heart rate in workers before and after a shift;

- Daily monitoring of blood pressure and electrocardiogram - Monitoring daily changes of functional parameters of the circulatory system (systolic (SBP) and diastolic blood pressure (DBP), the daily pressure index, heart rate variability and autonomic regulation).

Hemodynamics indicators are important indicators of the final adaptive result, i.e. ability of an employee to adapt to production and labor factors.

The approach to selection of tests was based on determination of an adaptation stage

based on the quantitative evaluation in the context of obtained information (in terms of integrated index).

Questionnaire survey, cognitive testing were carried out in all the groups of workers before and after the shift during the first week of the first month of the observation, during the second week of the second month of the observation, and during the last week of the month of observation. 24-hour blood pressure monitoring and HM-ECG were conducted in the employees selected by the criteria of correspondence to the average group length of employment and age, at the same time with the survey. Before and after the shift monitoring of blood pressure and heart rate was conducted for all the employees during each shift during the entire observation period. Evaluation of the marker functional parameters in employees was conducted before and after the work shifts and rest periods.

The study included 251 surveys. The total number of responses to all the survey indicators equaled 7 293. The results from the model chart were moved to an electronic database for further mathematical processing.

24-hour blood pressure monitoring was conducted with the help of Schiller-BR-102 Plus and MT-300 software (oscillometric and auscultatory methods) (Schiller AG, Switzerland, Registration Certificate № FS 2006/813 from 30.05.2006 to 30.05.2016) using a standard procedure. In the course of the research, we determined the parameters of the daily profile of blood pressure and heart rate, blood pressure variability, and daily indexes of blood pressure. HM-ECG was done with the help of Microvit MT-101 and MT-200 software (Schiller AG, Switzerland, Registration Certificate № FS 2006/813 from 30.05.2006 to 30.05.2016). We also measured the variability indicators of the heart rate (SDNN, SDANN, SDNNidx, rMSSD, pNN50, circadian rhythm profile). We conducted 72 studies. Blood pressure and heart rate were measured using UA – 777 A\D, Japan. Registration Certificate № FSZ 2011 /09642 of 11 May 2011. We conducted 10886 studies. The obtained data on the labor conditions, occupational route, survey results, test results, and examination results were formalized and entered into an electronic database for further mathematical analysis.

The mathematical analysis of the results was performed with the help of STATISTICA for Windows 7.0, Statistica 6,0 (StatSoft, Inc., USA) using a MS Excel script program module. The differences were considered statistically significant at $p<0.05$.

Results and Discussion. Labor conditions of the miners were found to present the following specific technology-determined hazardous production factors: sylvinite dust in the workplace air and during extraction of potash ore; production noise and vibration from electric rigs, operating combined machines, local ventilation fans; lack of natural light, hardness and high intensity of the working process. The works are performed in limited space under regional and overall physical dynamic load, in standing position up to 60% of time, combined with the overall and local vibration.

Workplace assessment showed that the labor conditions of miners, with the account for exposure to combined hazardous production factors, are rated as the 3rd level of the 3rd class of hazard. The main production factors affecting the workers include sylvinite dust, noise, and psychoemotional strain.

Various physiological indicators used in the assessment of the functional state have different information value and, correspondingly, bear various significance in terms of contribution to the prenosological diagnostics. It has been established that lower adaptation capabilities result in weaker overall functional state due to ambivalent changes in the indicators since the processes of compensation and maintenance of homeostasis flow differently depending on the original functional state.

Analysis of the obtained test results showed that the adaptation mechanisms in the group of employees working 10-hour shifts are stressed. The signs include ill health in 29% of employees ($p=0.0029$) according to subjective evaluation, and slowing down in the mental process admitted by 16% of employees.

Fatigue resulted in increased number of employees with lack of desire to work (43.5%, $p=0.0081$). Ill health, according to subjective evaluation, was noted in 43.5%, $p=0.0081$) including 31.5% ($p=0.0029$) that noted ill health before the start of a shift, and 24% ($p=0.0001$) at the end of the shift which implies low endurance. Labor capacity after a work shift was lower as well ($p=0.0196$).

The number of workers with a high level of anxiety before the work shift in the group of employees working 11 hour shifts appeared to increase (the share of employees working 11-hour shifts – 43.8%, the share of employees working 8-hour shifts - 29%, $p=0.0039$), and the number of

employees with a high level of anxiety after the shift appeared to decrease (the share of employees working 11-hour shifts – 16%, the share of employees working 8-hour shifts - 29%,). Decrease in the number of employees with anxiety is caused by fatigue in 42.4% of employees ($p<0,001$) at the end of the shift. These changes signify the development of uncompensated fatigue, and insufficient recovery during a rest period.

The group of employees working 12-hour shifts had a high number of workers experiencing fatigue before a work shift (10,3%, $p=0,04$), and increased number of workers experiencing lower performance capacity before and after a work shift ($p=0.0092$ and 0.0146 respectively) which indicates adaptation failure (Tables 1 and 2).

Work shifts that are longer than 8 hours were proved to cause changes in the functional state of health which cannot be considered satisfactory. First of all, it manifested in the change of the indicators that characterize the performance of the circulatory system – the heart rate tends to go up after a work shift, with a risk of tachycardia.

With 8-hour work shifts, the level of adaptation was estimated as "satisfactory" (heart rate up to 75/min, blood pressure up to 120/80 mmHg) and "strained adaptation mechanisms" (heart rate up to 85/min, blood pressure up to 135/85 mmHg) resulting from the work load. 10- and 11-hour work shifts were found to go with "stressed adaptation mechanisms" (heart rate up to 85/min, blood pressure up to 135/85 mmHg). Work shifts that were longer than 12 hours were found to go with "unsatisfactory (low) adaptation" (heart rate up to 95/min, blood pressure up to 140/85 mmHg) and "adaptation failure": heart rate > 95/min, blood pressure > 140/85 mmHg. [1, 4].

Analysis of the medical records during the observation period did not reveal an increase in the number of incapacity to work related to the diseases of the circulatory, nervous, and respiratory systems. No deterioration of employees' health was revealed

Table 1

The level of adaptation in employees working various hours (before the shift), % of the total number of employees in the study groups

Length of shift	8 hours	10 hours	11 hours	12 hours
Satisfactory adaptation*	69	51	49	34
Stressed adaptation mechanisms*	17	16	17	10
Unsatisfactory (low) adaptation *	9	24	18	29
adaptation failure*	5	9	16	27

*- stages of adaptation by the integrated index (total points and correlation of the rating scales)

Table 2

The level of adaptation in employees working various hours (after the shift), % of the total number of employees in the study groups

Length of shift	8 hours	10 hours	11 hours	12 hours
Satisfactory adaptation*	59	47	41	35
Stressed adaptation mechanisms*	21	23	22	11
Unsatisfactory (low) adaptation *	13	11	14	19
adaptation failure*	7	19	23	35

*- stages of adaptation by the integrated index (total points and correlation of the rating scales)

based on medical referrals to the local health clinics. However, the researchers registered signs of exhaustion of the adaptation mechanisms resulting from work shifts that are longer than 8 hours.

Conclusions. In the mining industry, potash ore extraction, in particular, work shifts that exceed 8 hours by 2 or more hours tend to result in disadaptation. Major functional disorders and adaptation failure are associated with the work shifts that are longer than 12 hours; in support of this statement are cases of dismissal from work for the reason of high blood pressure > 160/90 mmHg. At the same time, adaptation stress and low adaptation do not depend on the length of work shifts and rest periods, while adaptation failure is observed after the work shifts indicating the involvement of

all the mechanisms and levels of adaptation. The accumulation of functional disorders resulting from 10- and 11-hour work shifts do not have significant differences and are characterized by stressed adaptation (functional disorders are on the psychological level), which is also important in terms of health. 8-hour work shifts are associated with “satisfactory adaptation”.

The suggested marker functional parameters used in the assessment of the performance of the central nervous system (autonomic division) and the circulatory system can help determine acceptable working hours (shift) and rest periods for miners involved in potash ore extraction. An acceptable work shift for miners involved in potash ore extraction should not exceed 8 hours.

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