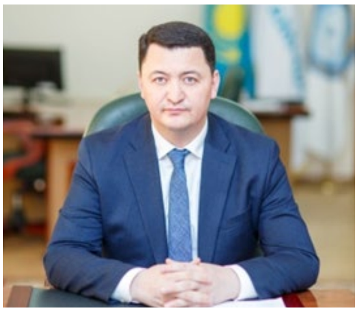


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PROSPECTS FOR THE DEVELOPMENT AND IMPLEMENTATION OF A METHODOLOGY FOR ANALYZING OCCUPATIONAL RISKS IN THE CONTEXT OF MODERN CHALLENGES TO OCCUPATIONAL SAFETY AND HEALTH OF THE WORKING POPULATION OF KAZAKHSTAN

The issue of creating safe working conditions for employees has become not only a social and economic concern but also a political one, and its resolution requires a comprehensive approach to health protection and labor longevity. The professional community is focused not only on developing legislative and regulatory acts in the field of occupational health and safety but also on conducting quality monitoring within the «human-technology-environment» system. This aims to determine safe working tenure by accounting for harmful factors in working conditions and predicting the risk of developing occupational diseases among workers in hazardous industries. The methodology for assessing occupational risks, taking into account exposure to adverse production environment factors and health indicators of workers, will enable employers in industrial enterprises to ensure workplace safety across many sectors of Kazakhstan's economy.

Ensuring the right of workers to work without the risk of losing their health is a priority in the state policies of many countries worldwide. Considering the socio-economic aspects of workers' occupational health, there is a global trend toward implementing risk assessment procedures through new organizational and legal forms.

According to the European Agency for Safety and Health at Work, since the adoption of the Framework European Directive 89/391/EEC, risk assessment has been the cornerstone of the European approach to occupational safety and health. Since 1996, the «Guidance on Risk Assessment at Work,» approved by the Director-General for Employment and Social Affairs, has been in effect in the European Union [1].

Occupational medicine and safety services in the United States, the United Kingdom, and other countries have conducted national discussions on the issue of risk [2,3].

Kazakhstan's integration into the global community requires improving working conditions and enhancing occupational safety, as well as harmonizing national legislation with international standards, agreements, and commitments, particularly within the framework of the European Union, the International Labour Organization (ILO), and the World Health Organization (WHO).

Numerous key WHO documents, including the «Health for All» strategy, General Programmes of Work, and several World Health Assembly resolutions, emphasize the need to protect and promote health and safety at work by preventing and controlling hazards in the workplace environment [4,5].

The ILO promotes the principles of decent work by advancing occupational safety, labor standards, social dialogue, and social protection for vulnerable categories of workers. To achieve this, each country must develop an effective national occupational safety system within the framework of joint efforts by the government and social partners. Safe working conditions are a fundamental human right and an integral part of the concept of «decent work». According to the ILO's definition, a production monitoring system should consist of several subsystems reflecting various working conditions and integral indicators, enabling dynamic tracking of occupational safety and the health status of workers across different production sectors [6].

In the assessment of occupational risk, the analysis of adverse factors in the production environment that affect workers' health is of great importance. Therefore, physical, chemical, and biological hazardous production factors are considered causal risk factors for the development of occupational diseases if their impact exceeds the maximum permissible concentrations (MPC) and maximum permissible levels (MPL) [7-9].

From the perspective of occupational medicine, the methodology and fundamental approaches to assessing various aspects of occupational risk based on working conditions, developed by the Research Institute of Occupational Medicine of the Russian Academy of Medical Sciences, can be considered well-developed for predicting health risk [10].

The assessment of occupational risks in the Republic of Kazakhstan is based on domestic principles and criteria for the hygienic regulation of working conditions, classified by levels of harm and danger, as well as the severity and intensity of work processes. The determination of safe working tenure in hazardous conditions and the prediction of the risk of developing occupational diseases are conducted using mathematical models based on probabilistic characteristics of health impairment due to the frequency of exposure to adverse production environment factors.

From this perspective, predicting occupational risk is an extremely complex task. When analyzing the frequency of various health deviations, whether in individuals or labor collectives, an innumerable number of indicators can be used, each of which can be considered a criterion of occupational risk [11, 12].

Methodology for Occupational Risk Assessment. *To assess the risk prediction of respiratory diseases development* under high concentrations of dust and gas aerosols in the workplace, the calculation of dust or gas dose load should be conducted using the following formula:

$$\mathbf{R = 38{,}2\ X_1 + 26{,}1\ X_2 + 17{,}5\ X_3 + 5{,}5\ X_4\ K}, \tag{1}$$

where,

X1 - Age of the worker, in years

X2 - Total work experience, in years

X3 - Duration of exposure to harmful aerosols, in years

X4 - Concentration of aerosols in the air of the work zone (maximum allowable concentration), in mg/m³;

K- Coefficient that reflects the severity of the work and the associated lung ventilation volume.

The value of dust exposure doses (DED) or risk factor X4 depends on the concentration of aerosols in the workplace air and the duration of their exposure. The calculation of the DED (in $mg \cdot m^{-3\cdot}$ year) is carried out according to the formula:

$$\mathbf{DED = A \bullet P}, \tag{2}$$

where,

A - average shift concentration of aerosols (X4), mg /m^3;

P - analyzed period of time (in years) (X_3).

Alongside the calculation of the integral indicator R, it is also recommended to calculate the permissible DED. The values of personal DED for workers should not exceed these permissible limits to ensure that exposure levels remain within safe boundaries.

The maximum permissible dust exposure dose (PDED) corresponds to a calculated risk of disease of 5% over a total work exposure of 30 years.

Assessment of Risk Prediction for Hearing Disorders. The severity of hearing impairments depends on noise parameters, including its intensity, spectral composition, duration of exposure during the workday, the length of time working under noise conditions, and individual sensitivity.

To assess the risk of vestibular disorders, it is necessary to calculate the dose of noise exposure per shift and the cumulative noise exposure over the period of employment while operating machinery.

The noise load level during the period of the technological operation is determined by the formula:

$$Д = \sum_{i=i}^{n} (pi2\ ti), \qquad (3)$$

where,
pi – sound pressure levels corresponding to sound levels Li
ti - time interval of noise exposure at level Li
n - total number of time intervals of noise exposure

The level of the zero dose of noise is carried out according to the formula:

$$\mathbf{LДТ= LДМN + 10lg\ (T/To)}, \qquad (4)$$

where,
L дмп - Equivalent (energy) frequency-corrected noise level for the year, dBA
T- work experience in the profession, in years
To- work experience is 1 year
Risk assessment for hearing impairment is conducted in accordance with ISO 1999-75 «Acoustics. Determination of occupational noise exposure and assessment of hearing impairment due to noise» (Table 1).

Table 1 - Probability of hearing impairment, (%)

Age, years	Work experience, years											
	10			20			30			40		
	Degrees of hearing loss											
	I	II	III	I	II	III	I	II	III	I	II	III
$LA_{экв}$ = 90 dBA												
30	12	0	0									
40	22	0	0	25	0	0						
50	33	0	0	35	3	0	37	3	0			
60	44	6	0	46	9	0	48	0	0			
$LA_{экв}$ = 100 dBA												
30	39	17	0									
40	47	25	5	62	32	6						
50	50	28	7	62	36	15	68	41	20			
60	60	37	19	71	44	25	76	48	30	82	53	33

Assessment of the risk of developing diseases associated with vibration exposure. Key risk factors for vibration-related pathology include: prolonged exposure in a vibration-prone profession (10-15 years), high vibration levels, and the presence of additional adverse factors in the working environment and process (static loads, cool microclimate, forced postures, etc.).

Medical-biological risk factors include: starting work at an age younger than 20 or older than 45, clinically significant osteochondrosis of the cervical and lumbar spine, asthenic syndrome, autonomic lability, frostbite or injuries.

To assess the risk of developing occupational diseases related to vibration exposure, it is necessary to consider both dose-based and tenure-based loads.

The relative dose of vibration represents the ratio of the actual dose to the permissible dose and serves as an indicator of vibration exposure over any period of employment:

$$D_B = \frac{D_f}{D_{per}}, \qquad (5)$$

Vibration exposures for workers during their employment are typically inconsistent due to changes in occupation, work location, technology, organization of labor, and work breaks, which affect the daily doses and the number of shifts per year.

The cumulative relative vibration dose serves as an indicator of vibration exposure over any period of employment and is determined by the formula:

$$D = d \cdot N \cdot T, \quad (6)$$

where,
d - relative vibration dose;
N - number of work shifts per year with a constant daily dose *d*;
T- years of work under vibration conditions with a constant dose *d* and number of shifts per year.

Assuming the permissible shift dose (D_v permissible = 1), the average number of work shifts in a calendar year (250), and a work period (T years) of 40 years, the permissible cumulative dose (D_v per) theoretically amounts to:

$$D_{v\ per} = 1 \cdot 250 \cdot 40 = 10000, \quad (7)$$

The permissible duration of work under the influence of vibroacoustic factors is calculated using the formul:

$$T = 10000/d \cdot N, \quad (8)$$

where,
d - relative shift dose over the period of employment,
N - number of work shifts per year,
T - safe duration of work

The assessment of health risks associated with vibration exposure is conducted in accordance with ISO 5349, «Vibration. Measurement and evaluation of human exposure to hand-arm vibration», and is presented in Tables 2 and 3.

Table 2 - Assessment of the probability of health impairment from the action of general vibration

Equivalent corrected accelerations, 2, м/с ^{2}	Health risk from general vibration %, years of service		Classes of labour conditions
	10	20	
≤1,0 (MPL)	-	-	2 permissible
0,22	0,08	0,13	3.1 (harmful 1 degrees)
0,45	0,3	0,4	3.2 (harmful 2 degrees)
0,9	1,0	1,8	3.3 (harmful 3 degrees)
1,8	5,0	7,0	4 dangerous

Table 3 - Assessment of the probability of health impairment from the action of local vibration

Equivalent corrected accelerations, м/с ^{2}	Health risk from local vibration %, with experience, years		Classes of labour conditions
	10	20	
	Signs whitening of the fingers	Signs whitening of the fingers	
≤ 2,0 (MPL)	8,7	34,8	2 permissible
2,8	17,4	>50	3.1(harmful 1 degrees)
4,0	34,7	>50	3.2 (harmful 2 degrees)
5,6	>68	>50	3.3 (harmful 3 degrees)
8,0	>50	>50	4 dangerous

Thus, for effective management of occupational safety and health and worker safety in industrial enterprises, it is necessary to: continuously monitor the levels of adverse factors in the work environment, replace outdated equipment, implement new techniques and technologies to minimize manual labor, analyze workers' health based on data from annual periodic medical examinations, accident reports, and industrial injury statistics, respond promptly to changes in factors affecting the safety of hazardous production sites and their personnel, conduct necessary preventive measures aimed at preserving the labor potential for future generations.

1. Overall, the system for monitoring professional risks is aimed at identifying and assessing existing risks, as well as developing mechanisms for their minimization. Risk management should be integrated into

the overall organizational management process. It is important to develop a specific strategy and tactics for effective risk management. Additionally, it is crucial not only to implement risk management but also to periodically review and update the measures and tools used for this management.

2. The use of workplace assessment results for working conditions and data from periodic medical examinations allows for the calculation of dose-based shift and cumulative exposures to harmful production factors. This helps determine safe work tenure and forecast the risk of developing occupational diseases.

3. The result of monitoring occupational risk is the quantitative assessment of the degree of health risk to workers from harmful and dangerous factors in the working environment and job demands, based on probability.

4. The occupational risk assessment monitoring system requires adherence to two main principles:

- Structured Risk Assessment: Risk assessment must be structured to account for all hazards and risks.
- Risk Mitigation: After identifying risks, decisions must be made regarding the feasibility of eliminating them, and a comprehensive set of organizational, technical, sanitary-hygienic, and preventive measures should be implemented to ensure occupational safety and health.

5. Interdepartmental and intersectoral collaboration between the Ministry of Health and the Ministry of Labour and Social Protection of the Population of Kazakhstan in the field of improving working conditions and preserving the health of industrial workers, as well as with executive authorities, state sanitary, environmental, and technical oversight bodies, professional unions, and employers, should be conducted within the framework of the Main Strategic Directions for ensuring occupational safety and health protection of the working population, which are approved by the Government on an annual basis.

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