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Research article

ASSESSING AND PREDICTING INDIVIDUAL OCCUPATIONAL RISK AND DETERMINING ITS EXACT CATEGORIES USING PROBABILISTIC METHODS

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Existing approaches to occupational risk assessment more often involve evaluating its group levels and individual risks are assessed less frequently. These approaches provide deterministic risk assessment which doesn't take into account uncertainty in risk categorizing when its values are close to boundaries between adjoining risks categories. It substantiates the necessity to assess occupational risk levels using probabilistic methods.

Our research object was occupational risk and the basic subject was distribution of individual occupational risk levels among workers. Our test group was made up of oil and gas extraction operators exposed to noise equal to 80–85 dBA at their workplaces (173 people). Our control group included oil and gas extraction operators and engineering and technical personnel occupationally exposed to noise equal to 60–77.8 dBA (259 people). We performed a priori assessment of occupational health risks; accomplished epidemiologic analysis of a cause-effect relation between health disorders and work; calculated group occupational health risks; calculated and predicted individual occupational risk using mathematical modeling of dependence between probable negative responses and working conditions, age, and period of employment; determined risk categories more precisely using fuzzy sets by calculating the membership function.

As a result, we established that proven individual risk levels were distributed unevenly ($1.06 \cdot 10^{-4}$–$1.47 \cdot 10^{-2}$) as per categories within a group characterized with a suspected average risk level. A category of proven individual risk levels was determined more precisely using fuzzy sets; after that distribution of probability of their membership was evaluated to detect that at the moment of the research a share of workers with their proven individual occupational risks falling into lower risk categories ($p > 0.5$) amounted to 89.6 %.

We attempted to predict risks for the whole employment period given that working conditions remained the same and no prevention activities were provided. Our prediction revealed that individual occupational risks would remain unacceptable for all workers in the test group and would amount to $2.53 \cdot 10^{-2}$–$3.51 \cdot 10^{-2}$; a risk category was also expected to become higher. Individual occupational risk would be categorized as average for most workers and as high for 23 % of them ($p < 0.5$).

Key words: *occupational risk, noise, probabilistic assessment, risk level categorizing, regression models, risk level prediction, sensorineural hearing loss, fuzzy sets.*

Existing methodical approaches to occupational risk assessment mostly involve assessing it on a group level [1–4] and much less frequently on an individual one [5]. In foreign practice occupational risk is also mostly calculated on a group level and the procedure usually involves epidemiologic evaluation of relationships between morbidity and working conditions as well as relative risk calculation [6–8].

These aforementioned approaches allow assessing occupational risks for big occupa-

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tional groups based on data on working conditions and workers' health predominantly focusing on occupational morbidity. These approaches provide deterministic risk assessment that can lead to occurring uncertainty in risk categorization when occupational risks rates are close to boundaries between adjoining risks categories.

Meanwhile, individual peculiarities related to development of diseases that occur due to exposure to adverse factors at a workplace determine the necessity to quantitatively assess occupational risks not only on a group level but also on an individual one. Categorization of group occupational risks performed for big occupational groups doesn't allow for peculiar distribution of individual risk rates as per different categories within a group.

The most significant deviations in individual risk assessment from group ones can be expected in a situation when group risk rate is close to a boundary between adjoining risk categories. If we analyze a probability to assign individual risks to a certain category, it will allow us to adjust results of group risk assessment and to create more adequate risk groups for subsequent prevention activities.

By now, certain methodical approaches to probabilistic occupational risk assessment have been suggested; they involve using fuzzy sets theory and aim to determine more precisely which risk category an individual risk belongs to [9].

These approaches seem the most vital when we assess occupational risks for workers exposed to noise levels deviating from hygienic standards at their workplaces. Noise, including its levels exceeding MPL, remains among leading factors that cause a developing occupational pathology, first of all, sensorineural hearing loss [10–13][1]. In several authors' opinion, this is due to growing mechanization and automation in various industries (oil extraction and processing, metallurgy, metal processing, civil engineering, construction, etc.) [14]. Therefore, there are a growing number of people who are exposed to noise at workplaces due to old equipment not conforming to sanitary-hygienic requirements [10, 14, 15][1]. Annually more than 3 million workers are occupationally exposed to noise levels that exceed maximum permissible ones [16].

Since employable age is now prolonged in the country due to the pension reform [17], it is truly necessary to predict occupational risks over the whole period of employment [18, 19]. Given that, we can conclude that it seems vital to assess occupational risks for workers exposed to occupational noise levels exceeding hygienic standards with probabilistic methods.

Our research aim was to assess and predict an individual occupational risk for workers exposed to occupational noise levels deviating from hygienic standards over the whole period of employment and to examine changes in risk categories using probabilistic methods.

Materials and methods. We analyzed data on working conditions (obtained by the special assessment of working conditions (SAWC) and industrial laboratory control), working experience and age; categories of working conditions were estimated in accordance with the Guide R 2.2.2006-05 "The Guide on hygienic assessment of factors related to working environment and labor process / Criteria and classification of working conditions"[2]; risks were categorized in accordance with the Guide R 2.2.1766-03 "The Guide on assessment of occupational risks for workers'

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[1] O sostoyanii sanitarno-epidemiologicheskogo blagopoluchiya naseleniya v Rossiiskoi Federatsii v 2020 godu: Gosudarstvennyi doklad [On sanitary-epidemiologic welfare of the population in 2020: The State Report]. Moscow, The Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing, 2021, 256 p. (in Russian).

[2] R 2.2.2006-05. Rukovodstvo po gigienicheskoi otsenke faktorov rabochei sredy i trudovogo protsessa. Kriterii i klassifikatsiya uslovii truda: utv. Glavnym gosudarstvennym sanitarnym vrachom Rossiiskoi Federatsii 29 iyulya 2005 g. [The Guide R 2.2.2006-05. The Guide on hygienic assessment of factors related to working environment and labor process. Criteria and classification of working conditions (approved by the RF Chief Sanitary Inspector on July 29, 2005)]. *KODEKS: an electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200040973 (August 17, 2021) (in Russian).

health. Organizational and methodical grounds, principles, and assessment criteria"[3].

We applied methodical approaches to probabilistic assessment of occupational risks belonging to a certain risk categories for workers employed in oil extraction and occupationally exposed to noise levels exceeding hygienic standards.

Our test group was made up of oil and gas extraction operators who were exposed to a noise level equal to 80–85 dBA at their workplaces (173 people, average age was 39.7 years; average working experience, 12.7 years). The reference group included oil and gas extraction operators and engineering and technical personnel who were exposed to noise levels equal to 60–77.8 dBA at their workplaces (259 people with their average age being 46.8 years; average working experience, 12.6 years).

Occupational health risks were assessed as per the following algorithm:

1. A priori occupational risk assessment based on SAWC results in accordance with the Guide R 2.2.1766-03 "The Guide on assessment of occupational risks for workers' health. Organizational and methodical grounds, principles, and assessment criteria"[3];

2. Epidemiologic analysis of cause-effect relations between health disorders and work;

3. Occupational group risk assessment;

4. Occupational individual risk assessment using mathematical modeling of a relationship between a probability of negative responses and working conditions, age and working experience;

5. Assessment of individual health risks due to work-related diseases using obtained model parameters;

6. Adjustment of risk categories using fuzzy sets procedure.

The suggested algorithm involved using a set of procedures including:

– assessing a cause-effect relation between health disorders and exposure to noise; the assessment was performed as per risk ratio (*RR*) and etiological fraction (*EF*) of negative responses.

– analyzing exposure –response relationship using logistic regression models that show dependence between a probability of health disorders and working conditions, age and working experience; the models were created using Statistica 6.0 software package [20] (1).

$$p_1 = \frac{1}{1 + e^{-(b_0 + b_1 x_1 x_2 + b_2 x_3)}}, \qquad (1)$$

where p_1 is a probability of a negative response (an occupational or a work-related disease); x_1 is a level of exposure to a factor; x_2 is working experience; x_3 is age; b_0, b_1, b_2 are parameters of a mathematical model.

The suggested model parameters were used to calculate predictive values of developing diseases and occupational risks by the age of 65 years. Health risk was determined as a probability of a disease multiplied by its severity[4]. A risk equal to $1 \cdot 10^{-3}$ and lower (low and negligibly low risks accordingly) was considered acceptable (permissible) occupational health risk.

Calculated occupational risk rates were considered to be deterministic values that were assessed and assigned into specific risk category according to the scale provided in Table 1 [9].

Probabilistic assessment of individual risk belonging to a certain category was performed by determining a membership function using a scale with fuzzy numbers built on the basis of deterministic scale showing occupational risk rates.

We applied trapezoid fuzzy numbers to determine what risk category various risk levels belonged to: negligibly low risk was within

[3] R 2.2.1766-03. Rukovodstvo po otsenke professional'nogo riska dlya zdorov'ya rabotnikov. Organizatsionno-metodicheskie osnovy, printsipy i kriterii otsenki: utv. Glavnym gosudarstvennym sanitarnym vrachom Rossiiskoi Federatsii 24 iyunya 2003 g. [The Guide R 2.2.1766-03. The Guide on assessment of occupational risks for workers' health. Organizational and methodical grounds, principles, and assessment criteria (approved by the RF Chief Sanitary Inspector on June 24, 2003)]. *KODEKS: an electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/901902053 (August 17, 2021) (in Russian).

[4] Professional'naya patologiya: natsional'noe rukovodstvo [Occupational pathology: the national guide]. In: N.F. Izmerov ed. Moscow, GEOTAR-Media, 2011, 784 p. (in Russian).

Table 1

The scale showing occupational risk rates

Occupational risk rates	Occupational risk categories
Lower than $1{\cdot}10^{-4}$	Negligibly low risk
$1{\cdot}10^{-4}$–$1{\cdot}10^{-3}$	Low risk
$1{\cdot}10^{-3}$–$1{\cdot}10^{-2}$	Moderate risk
$1{\cdot}10^{-2}$–$3{\cdot}10^{-2}$	Average risk
$3{\cdot}10^{-2}$–$1{\cdot}10^{-1}$	High risk
$1{\cdot}10^{-1}$–$3{\cdot}10^{-1}$	Very high risk
$3{\cdot}10^{-1}$–1	Extremely high risk

0, 0, 0.00005, 0.00033; low risk, 0.00005, 0.00033, 0.00078, 0.00325; moderate risk, 0.00078, 0.00325, 0.0775, 0.015; average risk, 0.0775, 0.015, 0.025, 0.0475; high risk, 0.025, 0.0475, 0.0825, 0.15; very high risk, 0.0825, 0.15, 0.25, 0.53; extremely high risk, 0.25, 0.53, 1.1[5].

To present the scale showing trapezoid fuzzy numbers used to assess occupational risk rates, we applied the following coordinate axes: X-axis showed risk rate and Y-axis showed a value of a membership function for this risk rate (Figure 1).

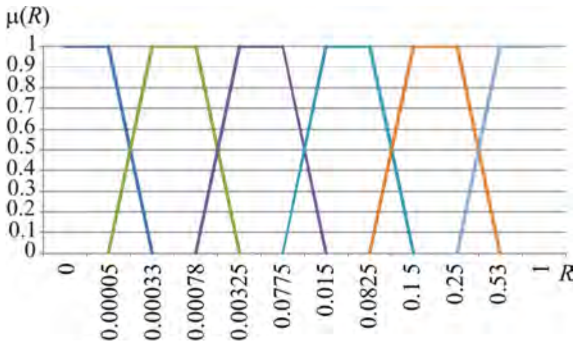

Figure 1. A graph showing the scale with trapezoid fuzzy numbers used to assess occupational risk rates

Use of trapezoid fuzzy numbers allowed determine more precisely what risk category a risk rate belonged to. Taking into account calculated estimates of a membership function for a fuzzy number that showed a probability of a risk belonging to a certain category form 0 to 1, we determined a risk rate more precisely; in case a membership function was equal to 1, a risk category did not need any further adjustment.

Given the calculated estimates of membership functions for a fuzzy number, a weight of a risk category (P_k) was determined as per the following formula (2):

$$P_k = \sum_i q_i \cdot \mu_{ki}(R^{occup}_{OD(WRD)}),$$
$$k = 1, 2, 3, 4, 5, 6, 7, \qquad (2)$$

where q_i is a weight contribution made by a risk category i to overall risk rate; k is significance of a risk category.

Weight contribution made by a risk category i to an overall risk rate (q_i) was calculated as per the Fishburne formula (3):

$$q_i = \frac{2(n-i+1)}{(n+1)n}, \ i = 1, 2, 3, 4, 5, 6, 7, \qquad (3)$$

where n is a number of risk categories.

The next step was to determine severity in order to determine a risk more precisely; it was done as per the formula (4):

$$SR_k = \sum_{k=1}^{7} \overline{r_k} \cdot P_k, \qquad (4)$$

where r is a value of a variable that shows a more precise risk as a disease with certain severity; $\overline{r_k}$ is the middle of each range on the scale showing risk rates; P_k is a weight of a risk category; SR_k is severity applied to determine a risk more precisely for each disease.

We applied trapezoid fuzzy numbers to determine what risk category those more precisely determined risk rates belonged to: negligibly low risk was within 0, 0, 0.042, 0.125; low risk, 0.042, 0.125, 0.208, 0.292; moderate risk,0.208, 0.292, 0.375, 0.458; average risk, 0.375, 0.458, 0.542, 0.625; high risk, 0.542, 0.625, 0.708, 0.792; very high risk, 0.708, 0.792, 0.875, 0.958; extremely high risk, 0.875, 0.958, 1, 1.

[5] Zade L. Ponyatie lingvisticheskoi peremennoi i ego primenenie k prinyatiyu priblizhennykh reshenii [A concept of a linguistic variable and its application in approximate solutions]. Moscow, Mir Publ., 1976, 166 p. (in Russian).

Table 2

Categorization of individual occupational risk rates

Risk category	A number of workers with a risk from this category (people)	A probability of workers belonging to a certain risk category (people)	
		0.51 – 0.99	1
Low:	34	11	23
Workers at a boundary with moderate risk category	11	–	–
Moderate:	121	45	76
Workers at a boundary with low risk category	26	–	–
Workers at a boundary with average risk category	19	–	–
Average:	18	13	5
Workers at a boundary with moderate risk category	13	–	–

Results and discussion. We performed a priori assessment of expected occupational risk as per a category of working conditions (noise level from 80 to 85 dBA corresponds to hazard category 3.1) in accordance with the Guide R 2.2.1766-03[3] and assigned this risk into "low risk" category; occupational risks for workers from the reference group were considered to be "negligibly low" (noise level was lower than 80 dBA, hazard category 2).

Medical examination and analysis of reports issued after previous periodical medical examinations allowed revealing 7 cases of occupational diseases among 173 workers from the test group (sensorineural hearing loss) as well as several other diseases that might be work-related including 40 cases of hypertension, 1 case of migraine, and 52 cases of functional disorders in the autonomic nervous system. 259 workers from the reference group turned out to have 1 case of sensorineural hearing loss, 66 cases of hypertension, 1 case of migraine, and 145 cases of functional disorders in the autonomic nervous system.

We didn't reveal any authentic cause–effect relations between diseases than might be work-related ones (hypertension, migraine, and functional disorders in the autonomic nervous system) and exposure to noise; therefore, all further occupational risk assessments were performed regarding only the detected occupational pathology, sensorineural hearing loss.

A probability of developing sensorineural hearing loss amounted to $3.91 \cdot 10^{-2}$ in the test group and to $3.86 \cdot 10^{-3}$ in the reference one. Additional probability of developing sensorineural hearing loss amounted to $3.52 \cdot 10^{-2}$.

Proven group risk rate, severity (0.3^4) of sensorineural hearing loss taken into account, amounted to $1.13 \cdot 10^{-2}$ ("average risk" category) and this rate didn't differ greatly from moderate risk. Given that, we calculated individual risk rates and determined categories of calculated risk rates more precisely.

Our assessment of exposure–effect relationship allowed us to obtain parameters of the mathematical model that showed a probability of developing sensorineural hearing loss depending on a noise level, working experience and age: $b_0 = -7.35$, $b_1 = 0.00014$, $b_2 = 0.074$. Proven individual risk rates in the test group that were calculated using these parameters varied from $1.06 \cdot 10^{-4}$ to $1.47 \cdot 10^{-2}$. Unacceptable occupational risks (higher than $1 \cdot 10^{-3}$, "moderate risk" and higher) were detected for 139 workers of 173 (80.35 % of the total number of people exposed to a noise level being higher than 80 dBA).

Table 2 provides the results of categorizing proven individual occupational risk rates that was performed using probabilistic assessment.

Table 3

Probabilistic assessment of individual risk belonging to a specific category at the age of 65 years

Risk category	A number of workers with a risk in this category (people)	A probability of workers belonging to a specific risk category (people)	
		0.51–0.99	1
Average	173	40	133
Workers at the boundary with high risk	40	–	–

More precisely determined risk rates are considered a basis for substantiating activities aimed at managing occupational risks in accordance with their category.

The suggested algorithm allowed assessing what category individual occupational risks belonged to; as a result, we were able to determine the following more precise categories of proven individual risks:

– occupational risk was categorized as "low" for 19.7 % workers from the test group but still 32.4 % of workers exposed to low risks were at the boundary with moderate risk category;

– occupational risk was categorized as "moderate" for 69.9 % workers from the test group; 21.5 % workers with moderate risk were at the boundary with low risk category, and 15.7 % were at the boundary with average risk category;

– occupational risk was categorized as "average" for 10.4 % workers from the test group; 72.2 % workers with average risk were at the boundary with moderate risk category.

We calculated predicted occupational risk rates by the age of 65 to establish that predicted risk rate would grow and reach values from $2.53 \cdot 10^{-2}$ to $3.51 \cdot 10^{-2}$. Probabilistic assessment of individual risk belonging to a certain category allowed categorizing this risk as being average (Table 3).

Probabilistic assessment of individual risk performed to determine its category more precisely indicates that proved individual risk will be categorized as average for the whole test group when they reach the age of 65 years; 23 % of them will be at the boundary with the high risk category.

Conclusion. Our research focused on examining workers' health under occupational exposure to noise levels deviating from hygienic standards. It was established that suspected risk determined by assessing SAWC results belonged to the average risk category. But still, individual proven risk rates occurring due to an occupational disease (sensorineural hearing loss) were distributed unevenly within the group (from $1.06 \cdot 10^{-4}$ to $1.47 \cdot 10^{-2}$). Low (acceptable) individual risk was detected for 19.7 % workers; moderate risk, 69.9 %; average risk, 10.4 % workers.

Having determined risk categories more precisely, we assessed distribution of probability of proven individual health risks belonging to specific risk categories. Our assessment revealed that at the moment of the research a share of workers with their individual risks belonging to lower rick categories with probability exceeding 0.5 amounted to 89.6 %.

Figure 2 shows the results obtained in assessment of proven individual risks belonging to specific risk categories at the moment of the research and at the moment when all workers would reach the age of 65 years.

We made an attempt to predict changes in individual health risk rates for the examined workers during the whole period of employment (up to the age of 65 years) and determined that if they continued working under the same conditions without any prevention activities provided for them, risk categories would be likely to grow. Proven individual risk rates will become unacceptable for all workers in the test group and will vary from $2.53 \cdot 10^{-2}$ to $3.51 \cdot 10^{-2}$. Proven individual risk will be categorized as average for most workers but it will be high for 23 % of them

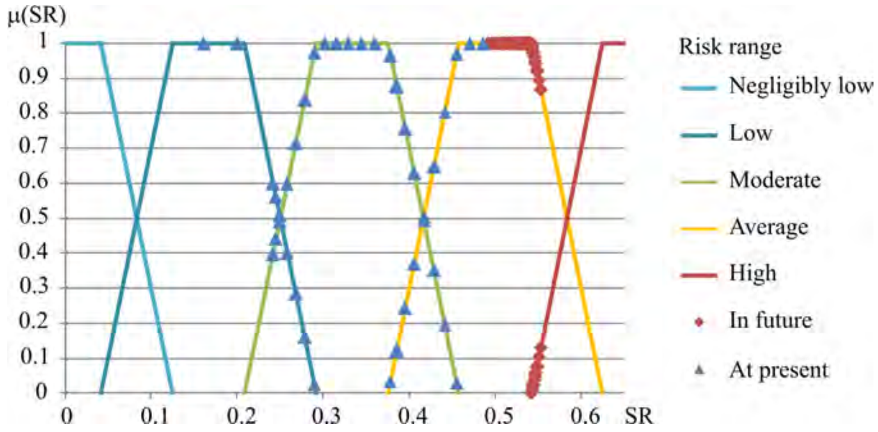

Figure 2. Assessment of proven individual risks belonging to specific risk categories at the moment of the research and at the age of 65 years

(p < 0.5). These workers should be considered a priority risk group and provided with preventive activities aimed at reducing occupational health risks.

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References

1. Roslyi O.F., Fedoruk A.A., Drugova O.G., Plotko E.G. Itogi otsenki professional'nogo riska dlya zdorov'ya rabotnikov po materialam SOUT, proizvodstvennogo kontrolya i professional'noi zabolevaemosti [The results of assessing occupational health risks for workers based on the materials of a special assessment of working conditions, production control and occupational morbidity]. *Upravlenie riskom dlya zdorov'ya rabotayushchikh i naseleniya v svyazi s khozyaistvennoi deyatel'nost'yu predpriyatii metallurgicheskoi promyshlennosti: materialy Vserossiiskoi nauchno-prakticheskoi konferentsii s mezhdunarodnym uchastiem*. Ekaterinburg, FBUN EMNTs POZRPP Rospotrebnadzora Publ., 2017, pp. 119–125 (in Russian).

2. Golovkova N.P., Kotova N.I., Chebotarev A.G. Otsenka urovnya professional'nogo riska u rabotnikov gorno-metallurgicheskikh predpriyatii po rezul'tatam spetsial'noi otsenki uslovii truda [Assessment of the level of occupational risk among workers employed at mining and metallurgical enterprises based on the results of a special assessment of working conditions]. *Sovremennye problemy meditsiny truda: materialy vserossiiskoi nauchno-prakticheskoi konferentsii, posvyashchennoi 80-letiyu akademika RAN N.Kh. Amirova*. Kazan', Kazanskii GMU, FGBNU “NII MT” Publ., 2019, pp. 51–54. DOI: 10.31089/978-5-6042929-0-7-2019-1-51-54 (in Russian).

3. Denisov E.I., Prokopenko L.V., Stepanyan I.V., Chesalin P.V. The loudness and hazard of noise; phenomenology, measurement, and evaluation. *Gigiena i sanitariya*, 2009, no. 5, pp. 26–29 (in Russian).

4. Denisov E.I., Tchesalin P.V. Occupationally related morbidity and its evidence. *Meditsina truda i promyshlennaya ekologiya*, 2007, no. 10, pp. 1–9 (in Russian).

5. Simonova N.I., Nizyaeva I.V., Nazarov S.G., Zhuravlyova E.A., Kondrova N.S., Stepanov E.G., Fasikov R.M., Grigorieva S.M. [et al.]. Comparative analysis of occupational risk evaluation results through various methodic approaches. *Meditsina truda i promyshlennaya ekologiya*, 2012, no. 1, pp. 13–19 (in Russian).

6. Xu Q., Yu F., Li F., Zhou H., Zheng K., Zhang M. Quantitative differences between common occupational health risk assessment models. *J. Occup. Health*, 2020, vol. 62, no. 1, pp. e12164. DOI: 10.1002/1348-9585.12164

7. Petereit-Haack G., Bolm-Audorff U., Romero Starke K., Seidler A. Occupational risk for post-traumatic stress disorder and trauma-related depression: a systematic review with meta-analysis. *Int. J. Environ. Res. Public Health*, 2020, vol. 17, no. 24, pp. 9369. DOI: 10.3390/ijerph17249369

8. Gunnarsson L.G., Bodin L. Occupational exposures and neurodegenerative diseases – a systematic literature review and meta-analyses. *Int. J. Environ. Res. Public Health*, 2019, vol. 16, no. 3, pp. 337. DOI: 10.3390/ijerph16030337

9. Zaitseva N.V., Shur P.Z., Alekseev V.B., Savochkina A.A., Savochkin A.I., Khrushcheva E.V. Methodical approaches to assessing categories of occupational risk predetermined by various health disorders among workers related to occupational and labor process factors. *Health Risk Analysis*, 2020, no. 4, pp. 23–30. DOI: 10.21668/health.risk/2020.4.03.eng

10. Shlyapnikov D.M., Shur P.Z., Alexeev V.B., Uhabov V.M., Novoselov V.G., Perevalov A.Ya. New potential of MTHFR gene variations application as an individual sensitivity marker in evaluation of occupational risk of arterial hypertension under exposure to nose. *Meditsina truda i promyshlennaya ekologiya*, 2016, no. 8, pp. 6–10 (in Russian).

11. Blaginina T.F., Bolotnova T.V. Sensorineural hearing loss as a predictor of endothelial dysfunction in some non-communicable diseases in the working population (a review of interdisciplinary studies). *Kubanskii nauchnyi medicinskii vestnik*, 2020, vol. 27, no. 2, pp. 113–126. DOI: 10.25207/1608-6228-2020-27-2-113-126 (in Russian).

12. Syurin S.A. Industrial noise and occupational noise-induced hearing loss at enterprises in the Russian arctic. *Bezopasnost' i okhrana truda*, 2020, vol. 82, no. 1, pp. 49–53 (in Russian).

13. Kuznetsova G.I. Vliyanie shuma na zdorov'e rabotnikov neftedobyvayushchei promyshlennosti [Effects of noise on health of workers employed in oil extracting industry]. *Zdravookhranenie Yugry: opyt i innovatsii*, 2021, vol. 28, no. 3, pp. 53–60 (in Russian).

14. Shaikhlislamova E.R., Volgareva A.D. Occupational pathology caused by the influence of the noise-vibration factor in the Republic of Bashkortostan: dynamics, clinical features. *Bezopasnost' i okhrana truda*, 2019, vol. 81, no. 4, pp. 38–41 (in Russian).

15. Zinkin V.N., Sheshegov P.M., Chistov S.D. The clinical aspects of occupational sensorineural impairment of hearing of the acoustic origin. *Vestnik otorinolaringologii*, 2015, no. 6, pp. 65–70 (in Russian).

16. Pankova V.B., Tavartkiladze G.A., Mukhamedova G.R. Occupational hearing loss: new approach to diagnostic, labour capacity examination and rehabilitation. *Meditsina ekstremal'nyh situatsii*, 2013, vol. 43, no. 1, pp. 25–29 (in Russian).

17. Kravchenko E.V., Suhoveeva A.A. Targets and current trends in the development of pension provision in Russia. *Ekonomika, predprinimatel'stvo i pravo*, 2021, vol. 11, no. 5, pp. 1063–1076. DOI: 10.18334/epp.11.5.112081 (in Russian).

18. Novikova T.A., Mikhailova N.A., Raikin S.S. Professional'nyi risk uskorennogo stareniya rabotnikov, zanyatykh vo vrednykh i opasnykh usloviyakh truda (obzor literatury) [Occupational risk of accelerated aging of workers employed in hazardous and adverse working conditions]. *Gigiena, ekologiya i riski zdorov'yu v sovremennykh usloviyakh: materialy mezhregional'noi nauchno-prakticheskoi konferentsii molodykh uchenykh i spetsialistov*, 2018, pp. 114–129 (in Russian).

19. Vlasova E.M., Ustinova O.Yu., Fainburg G.Z., Petrov A.N. Health damage risk for workers in harmful and dangerous working conditions and possibility of its minimization. *Aktual'nye problemy ohrany truda i bezopasnosti proizvodstva, dobychi i ispol'zovaniya kalino-magnievykh solei: materialy I Mezhdunarodnoi nauchno-prakticheskoi konferentsii*. Perm', 2018, pp. 11–24 (in Russian).

20. Fokin V.A. Health risk assessment for workers in the extractive industries under conditions of noise exposure above 80 dBA. *Meditsina truda i promyshlennaya ekologiya*, 2020, vol. 60, no. 11, pp. 867–869. DOI: 10.31089/1026-9428-2020-60-11-867-869 (in Russian).

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