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Research article

Improving the procedure for group expert assessment in the analysis of professional risks in fuel and energy companies

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Abstract

The lack of a unified approach to the assessment of professional risks in fuel and energy companies (FEC) in the national regulatory environment and a high degree of subjectivity of the results of hazard identification and risk assessment makes mathematically sound recruitment of an expert group urgent and necessary. The article presents the results of a comprehensive study on hazard identification and risk assessment at 6,105 workplaces in 24 branches of a FEC company based on the application of the expert assessment method and a scientifically sound qualitative and quantitative selection of experts. The priority vectors of factors are determined, global priorities are calculated, the size of the expert group (15 persons) is determined and mathematically substantiated for carrying out hazard identification and risk assessment at workplaces with sufficient reliability of results. For the first time, a set of factors characterizing the FEC companies that influence the determination of professional competence of experts is proposed. The formed expert group presented more precise, objective and consistent results of risk assessment. Standards for free distribution of personal protective equipment (PPE) and wash-off agents to 7,234 company employees for implementation and trial use were developed. A fragment of the results obtained for a driller's workplace is presented. This approach allows a significant increase in objectivity and efficiency of the professional risk management system and provision of the PPE to employees in the concept of a risk-oriented approach helping to prevent industrial injuries and improve the level of occupational safety culture in fuel and energy companies taking into account global practice.

Keywords

risk-based approach; hazard identification; professional risk assessment; expert group; expert competence

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Introduction.

The paradigm of implementing a proactive risk-oriented approach is one of the fundamental conditions for a successful execution of the provisions of GOST R ISO 45001-2020 "Occupational safety and health management systems. Requirements and guidance for use" identical to the international standard ISO 45001:2018 [1]. In particular, the practice of foreign countries clearly confirms the efficiency of using a risk-oriented approach in providing employees with personal protective equipment (PPE) [2-4].

Currently, there are no regulated criteria for the mechanism for assessing the competence and recruiting an expert group to identify hazards and assess risks at workplaces in the fuel and energy companies (FEC). This necessitates improvement and experimental implementation. Given the specificity of the transformation of labour legislation[1] and the complexity of industry specificity, the

[1] Order of the Ministry of Labour of Russia dated October 29, 2021 N 767n "On approval of the Unified standards for the issuance of personal protective equipment and wash-off agents".

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discussion of practical aspects of implementing the risk-oriented approach in the FEC companies is particularly relevant [5, 6].

The expert assessment method chosen in this paper as a tool for improving the process of hazard identification and risk assessment at workplaces is widely used in various fields in cases where other methods for obtaining the necessary information are inapplicable or insufficiently efficient [7]. For example, in [8], the experts assessed the risks during construction of transportation infrastructure facilities. In article [9], the expert assessment method was used for the dynamic probabilistic analysis of accidents at construction sites. The involvement of experts in risk assessment and decision-making related to safety is considered in [10]. It is recommended to set up commissions or teams at the enterprise to assess the professional risks at workplaces [11]. The expert assessment method is used in expert examination of hazardous production facilities with prediction of the most optimal membership of the expert group [12] as well as in the analysis of hazard related to mothballed or abandoned oil and gas wells [13].

When applying the expert assessment method, the problem of selecting a team of competent experts whose objectivity and reliability of the assessment results would not be subject to doubt is of fundamental importance. Formation of such a team, both in terms of membership and size, is carried out exclusively using mathematically sound algorithms. Therefore, a wise solution of the problem of selecting experts directly affects the result of ensuring safe working conditions.

The objective of the study is mathematical substantiation of the qualitative and quantitative selection of an expert group for the practical implementation of a risk-oriented approach to providing the PPE to the fuel and energy sector employees.

The objective determines the formulation and solution of the main tasks:

• study of the practice of applying the expert assessment method in risk analysis;

• determination of criteria for the formation of an expert group for practical implementation of the risk-oriented approach to providing the employees with the PPE;

• formation of an expert group with a scientific rationale for identifying factors affecting the competence of experts;

• development of methodological principles for issuing the PPE to employees based on results of risk assessment at 6,105 workplaces.

Implementation of the proposed mechanism for improving the identification of hazards and risk assessment at workplaces in fuel and energy companies based on the use of the expert assessments method and scientifically grounded qualitative and quantitative selection of experts considerably increases the efficiency of the procedure for selecting the PPE with regard for the global trends and legislative requirements in the concept of the risk-oriented approach.

Methods.

The problem of high-quality and efficient risk management is a complex and urgent task. Risk assessment procedure is widely used in various industries. There are different risk assessment methods that are constantly being improved and kept up-to-date. Article [14] presents an impressive overview of numerous assessment methods applied using bibliometric analysis. Paper [15] gives an overview of scientific publications from 2000 to 2009 on the study, development and classification of the main methods of analysing and assessing the risks at workplaces. Article [16] analyses the works published from 2000 to 2019 and describing the evolution of risk level assessment methods. The publications on risk assessment methods adopted in mining industry were studied, and the need for the implementation of the latest reliable risk assessment methods in mining sector was specified [17, 18].

Identification of hazards and risk assessment at the enterprise under study was conducted by an expert group using the Fine – Kinney method [19][2]. This method of assessing professional risks is applied in both Russian [20-22], and foreign studies [23, 24]. To increase the degree of objectivity

[2] Kinney G.F., Wiruth A.D. Practical Risk Analysis for Safety Management. China Lake: Naval Weapons Center, 1976, p. 20.

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of expert assessments regarding the problem under consideration, the opinions of several experts – competent specialists – should be taken into account. It is important to form an expert group in such a way that the results of expert assessment are consistent, high-quality and reliable.

Deputy chief engineers for labour protection, industrial and fire safety were selected as experts for identification of hazards at workplaces and risk assessment using the Fine – Kinney method. The selection of such specialists as potential experts was due to their production experience, core education and specific nature of the duties performed. Thus, 22 employees were involved in identification of hazards and risk assessment. However, the results of assessment showed a low degree of consistency (concordance coefficient less than 0.5), which became the basis for a scientifically grounded qualitative and quantitative selection of the expert group.

The procedure for selecting the experts can be divided into two main stages: drawing up a list of potential candidates n for conducting an expert examination of companies R and evaluating them in order to select the most competent professionals h, with $n > h$, who scored the maximum competence coefficients W [25].

To determine the professional competence of experts based on analysis of the available methods for forming expert groups and taking into account the sector-specific issues, the factors that affect the competence of experts in the matters under consideration were identified [25, 26]. These factors were presented to a group of independent experts with a proposal to select five that mostly affect the competence of experts in the field of hazard identification and risk assessment. Taking into account the responses of all experts, the following five factors were identified using mathematical processing:

1. Length of service. Total work experience of the expert is taken into account.

2. Length of service in the field of operational surveillance in a fuel and energy company. Work experience in the field of industrial safety, namely, operational surveillance in a fuel and energy company, is taken into account.

3. The degree of risk perception. This factor allows determining the expert's readiness for risk and understanding its necessity and advisability.

4. Analytical style of personality. The experts who are able to analyse a large volume of information and pay attention to details are identified. Such qualities will allow a more precise identification of hazards and risk assessment at workplaces.

5. The number of violations in the area of providing the PPE to fuel and energy company employees. Violations identified in 22 branches of the fuel and energy company where the experts were responsible for this area of activity for three years are taken into account.

The above set of factors, typical for fuel and energy companies, is proposed for the first time.

Table 1 presents these factors as well as weight coefficients for each factor determined depending on the answers of potential experts.

Table 1

Professional competence of experts

Factors	Value of weight coefficient		
1	1-5 years 0.2	5-10 years 0.3	> 10 years 0.5
2	– 0	1-5 years 0.4	> 5 years 0.6
3	> 20 points 0	< –30 points 0.4	From –10 to +10 points 0.6
4	3rd place 0.2	2nd place 0.3	1st place 0.5
5	> 10 violations 0.2	1-10 violations 0.3	– 0.5

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To determine the level of risk perception, the potential experts were tested using the A.M.Schubert method. This 25-item survey is designed to determine the degree of risk readiness that could lead to adaptation in various life situations. The risk scoring system is used to analyse the questionnaire results. Overall test scoring is determined using a continuous scale reflecting deviations from the average value. Positive answers indicate risk readiness. Test scoring scale varies from –50 to +50 points.

It was ascertained that a score less than –30 points indicated excessive caution, from –10 to +10 – average risk readiness, and over +20 points – high risk readiness. High risk readiness is accompanied by a low motivation to prevent failures and is directly proportional to the number of mistakes made.

To analyse the analytical style of personality, an assessment of own personality style using the DISC typology was applied. This method is widely used in different companies. It is applied to determine personality styles for the purposes of leadership and communication management in the study [27], in paper [28] – to raise the company's productivity by increasing the efficiency of communications, in article [29] – when forming the company's employee pool. DISC is a methodology based on human behaviour which is formed by two axes in four sectors. One of the axes characterizes the level of activity, the other one, openness and control of interaction with the environment. Thus, four sectors are formed:

- High persuasiveness. Active.
- High responsiveness. More interested in people.
- Low persuasiveness. Reactive.
- Low responsiveness. Focused on solving the problem.

Four personality styles are formed: assertive, player, kind soul and analyst. In order to identify hazards and assess risks, it is important to have such qualities as attentiveness, meticulousness, concentration on details, and structuredness. A person with the analytical personality style has these qualities. The more this personality style prevails in an expert, the more qualitatively the expert examination will be carried out.

Algorithm for determining the professional competence of experts:

The sum of points scored by the *i*-th expert for all factors is calculated

$$\mathrm{SumX}_i = \sum_{j=1}^{m} a_{ij} ,$$

where m is the number of factors, $m = 5$; a_{ij} is the value of the weight coefficient scored by the i-th expert on the j-th factor.

The sum of factor points for all experts is determined:

$$\mathrm{SumF}_j = \sum_{i=1}^{n} a_{ij} ,$$

where n is the number of experts, $n = 22$.

The weight coefficient of experts for all factors is calculated:

$$W_i = \frac{\sum_{j=1}^{m} a_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{m} a_{ij}} ;$$

$$\sum_{i=1}^{n} W_i = 1 .$$

Table 2 shows the results of calculating weight coefficients for experts and factors.

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Table 2

Weight coefficients of experts

Number of expert	Factors					SumX$_i$	W_i
	1	2	3	4	5		
1	0.5	0.6	0	0.2	0.3	1.6	0.039
2	0.5	0.6	0.6	0.5	0.5	2.7	0.066
3	0.3	0.4	0.6	0.5	0.3	2.1	0.051
4	0.2	0.4	0.6	0.3	0.3	1.8	0.044
5	0.3	0.6	0	0.2	0.5	1.6	0.039
…	…	…	…	…	…	…	…
21	0.3	0.6	0	0.3	0.3	1.5	0.036
22	0.3	0.4	0	0.5	0.3	1.5	0.036
SumF$_j$	7.7	11	7.4	7.5	7.6	41.2	1

For a more precise assessment of the expert's competence, weight coefficients were calculated based on the data from Table 2 for each factor. The calculation results are presented in Table 3. Then, the weight coefficients of experts for all $W2_i$ factors and the sum of the expert's weight coefficients for all factors SumE$_i$ are calculated. Taking into account the obtained weight coefficients, the potential experts were ranked according to their professional competence level.

Table 3

Weight coefficients of experts by factors

Number of expert	Factors					SumE$_i$	$W2_i$
	1	2	3	4	5		
1	0.065	0.055	0.000	0.027	0.039	0.186	0.037
2	0.065	0.055	0.081	0.067	0.066	0.333	0.067
3	0.039	0.036	0.081	0.067	0.039	0.263	0.053
4	0.026	0.036	0.081	0.040	0.039	0.223	0.045
5	0.039	0.055	0.000	0.027	0.066	0.186	0.037
…	…	…	…	…	…	…	…
21	0.039	0.055	0.000	0.040	0.039	0.173	0.035
22	0.039	0.036	0.000	0.067	0.039	0.181	0.036
Total points	1	1	1	1	1	5	1

Using the hierarchy analysis method proposed in [30-32], the vector of factor priorities was determined (Table 4). It represents a relative weight of factors. The higher the priority value, the more significant the corresponding factor. The hierarchy analysis method is applied to solve such problems, since it is based on expert assessments and allows taking into account an arbitrary number of factors [31, 32].

Table 4

Matrix of pairwise comparisons of factors

Factors	1	2	3	4	5	Geometric mean	Vector of priorities
1	1	0.5	0.333	1	0.5	0.608	0.108
2	2	1	2	3	2	1.888	0.334
3	3	0.5	1	3	2	1.552	0.275
4	1	0.333	0.333	1	0.333	0.517	0.092
5	2	0.5	0.5	3	1	1.084	0.192
Sum						5.650	

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To check the consistency of priorities, λ_{max}, the maximum eigenvalue of the matrix is first calculated by summing the products of columns by the priority vector. In this case, $\lambda_{max} = 5.187$. The closer λ_{max} to the matrix dimension, the more consistent the result [31]. The consistency index (CI) shows a deviation from consistency in the hierarchy analysis method,

$$CI = \frac{\lambda_{max} - m}{m - 1} = 0.047.$$

Next, the random consistency index (RCI) is determined. This is a calculated value for matrices of each order; the RCI for a matrix of order 5 is 1.12 [30]. The ratio of the CI to the RCI is called the consistency ratio (CR). The calculated CR value is 0.042. CR value less than or equal to 0.10 indicates the consistency of assessments in the matrix [31]. Table 4 shows that factors 2 (work experience in the field of operational surveillance in a fuel and energy company) and 3 (degree of risk perception) were identified by the expert group as most important for selecting the experts to be involved in hazard identification and risk assessment at workplaces.

Global priorities of the experts are identified taking into account the vector of factor priorities. In order to calculate global priorities (Table 5) for each expert it is necessary to determine the sum of weight coefficients of experts for each factor (see Table 3) multiplied by the corresponding vectors of priorities (Table 4). From Table 5 it is clear that the highest global priority is given to experts 12, 21, 15, 9, 18, 6, 3, 14, 5, 2, 17, 20. This means that such experts have advantages in forming groups for hazard identification and risk assessment at workplaces.

Table 5

Results of calculating global priorities of experts

Number of expert	Factors					Global priority
	1	2	3	4	5	
1	0.065	0.055	0.000	0.027	0.039	0.035
2	0.065	0.055	0.081	0.067	0.066	0.066
3	0.039	0.036	0.081	0.067	0.039	0.052
4	0.026	0.036	0.081	0.040	0.039	0.048
5	0.039	0.055	0.000	0.027	0.066	0.037
6	0.026	0.036	0.081	0.067	0.066	0.056
7	0.039	0.036	0.081	0.067	0.039	0.052
8	0.039	0.036	0.000	0.027	0.039	0.026
9	0.039	0.036	0.000	0.067	0.039	0.030
10	0.039	0.036	0.054	0.067	0.039	0.045
11	0.039	0.036	0.081	0.027	0.039	0.049
12	0.065	0.055	0.081	0.067	0.066	0.066
13	0.039	0.055	0.000	0.027	0.066	0.037
14	0.065	0.055	0.000	0.040	0.039	0.036
15	0.065	0.055	0.000	0.027	0.026	0.033
16	0.026	0.036	0.081	0.067	0.039	0.051
17	0.065	0.055	0.081	0.027	0.066	0.063
18	0.039	0.036	0.081	0.027	0.026	0.046
19	0.039	0.055	0.054	0.040	0.039	0.049
20	0.065	0.055	0.081	0.027	0.039	0.058
21	0.039	0.055	0.000	0.040	0.039	0.034
22	0.039	0.036	0.000	0.067	0.039	0.030

At the next stage, the size of the expert group is determined, i.e. the boundary is drawn that determines the required number of experts to perform hazard identification and risk assessment ensuring sufficient reliability of the results.

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The required number of experts from among the potential experts according to papers [25, 31] is calculated using the formula of non-repeated random sampling

$$h = \frac{t^2\sigma^2 n}{\Delta^2 n + t^2\sigma^2},$$

where t is confidence coefficient, $t = 3$ at a probability level $P = 0.997$ [25]; σ^2 is sample variance for data (see Table 3), $\sigma^2 = 0.024$; Δ is the maximum sampling error, $\Delta = 0.07$.

Thus, the required number of experts to carry out hazard identification and risk assessment at workplaces is $h = 15$ persons at a probability of 0.997 and a sampling error of no more than 7 %.

Discussion of results.

A selected expert group of 15 persons identified hazards and assessed risks using the Fine – Kinney method at all workplaces in the company to determine the list of the PPE and wash-off agents. As an example, a fragment of the results obtained for a driller's workplace is presented. The expert group drew up a register of hazards and determined the probability, susceptibility and consequences of each hazard for the employee. Table 6 presents the risk level and the need to issue the PPE, which were determined according to the classification of professional risk levels using the Fine – Kinney method. The professional risk index (PRI) was calculated applying the Fine – Kinney method:

$$PRI = Pr \cdot Susc \cdot Cons,$$

where Pr is probability; Susc, susceptibility; Cons, consequences of the event onset.

Table 6

Classification of professional risk levels using the Fine – Kinney method

PRI, points	Risk level	The need to take action
From 0 to 20	No risk or negligible risk	No action required
From 21 to 70	Low moderate risk	Action required, but enough time to plan it
From 71 to 200	Medium significant risk	Planning and implementation of actions in a short time frame required
From 201 to 400	High risk	Urgent action required
Over 400	Extremely high risk	Stopping activity required before taking action

PRI calculation data for individual hazards identified at the driller's workplace (slippery, icy, greasy, wet surfaces; rotating or moving equipment parts or tools; sharp edges and burrs; physical overload due to excessive efforts when lifting and moving objects and parts; increased noise levels and other unfavourable noise characteristics) are presented in Table 7. The PRI was determined similarly for all the identified hazards. PRI calculation results revealed hazards with a negligible risk (e.g. sharp edges and burrs). In accordance with the Rules[3], the employer has the right not to issue the PPE for hazards whose risk level will not result in harming the employee's health during work, the PPE for such hazards was not selected.

Hazards with a low moderate risk that require attention (e.g. slippery, icy, greasy, wet surfaces), medium significant (e.g. rotating or moving parts of equipment or tools) and high (e.g. physical overload with excessive physical effort when lifting and moving objects and parts) risk levels were identified that require planning and implementation of actions in a short time frame and urgent measures,

[3] Order of the Ministry of Labour of Russia dated October 29, 2021 N 766n "On approval of the Rules for providing employees with personal protective equipment and wash-off agents".

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respectively. For certain hazards, the PPE was selected from the list in Appendix N 2 to the Unified Standard Guidelines[4].

Based on the assessment of professional risks, the expert group selected a list of the PPE for each workplace. For example, for the driller's workplace, the characteristics of special footwear were expanded, the protective "anti-slip" characteristic was added, and a support belt for the abdomen and lower back was proposed taking into account the high risk of hazard "Physical overload due to excessive physical effort when lifting and moving objects and parts". These items were not previously provided for in the Consolidated list of free issuance of special clothing, special footwear and other personal protective equipment to employees of the considered fuel and energy company.

Table 7

Calculation of professional risk index

Hazard	Hazardous event	Probability		Susceptibility		Consequences		PRI
		Assessment	Points	Assessment	Points	Assessment	Points	
Slippery, icy, greasy, wet surfaces	Fall of an employee due to a loss of balance while slipping and moving	Highly probable	6	From time to time (weekly)	3	Minor accident (including group accident) with temporary disability	3	54
Rotating or moving parts of equipment or tools	Hitting an employee by a tool when used incorrectly, hitting by rotating or moving parts of equipment	Highly probable	6	From time to time (weekly)	3	A serious accident without serious consequences and disability	7	126
Sharp edges and burrs	Cutting of an employee's soft tissues by sharp edges and burrs	Non-typical, but possible	3	From time to time (weekly)	2	Minor accident (including group accident) with temporary disability	3	18
Physical overload due to excessive physical effort when lifting and moving objects and parts	Damage to the musculoskeletal system of an employee from physical overload due to excessive physical effort when lifting and moving objects and parts	Highly probable	6	Regularly (every working day, shift)	6	A serious accident without serious consequences or disability	7	252
Increased noise levels and other adverse noise characteristics	Impairment of auditory acuity, dullness of hearing, deafness due to exposure to elevated noise levels and other adverse noise characteristics	Highly probable	6	From time to time (weekly)	3	A serious accident (including a group accident) with loss of ability to work for a long period, occupational disease, disability	15	270

It should be noted that when assessing the risks, the initially formed group of 22 experts in this profession underestimated the probability of occurrence of the hazard "Slippery, icy, greasy, wet surfaces" and the risk level of hazard was determined as negligible, not requiring any action. However, statistical data on accidents that occurred in the company in the period from 2006 to 2020 indicate a high probability of the occurrence of this hazard. This example additionally confirms that the expert group formed using the method proposed in the study presented more precise, objective and consistent risk assessment results.

[4] Order of the Ministry of Labour of Russia dated October 29, 2021 N 767n "On approval of the Unified Standard Guidelines for the issuance of personal protective equipment and wash-off agents".

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Thus, the application of the proposed approach made it possible to identify hazards at each workplace and select an efficient set of the PPE as a result of assessing professional risks taking into account the expert assessment.

Conclusion.

The accomplished study, taking into account the global practice of implementing a risk-oriented approach, made it possible to substantiate and implement a mechanism for improving the process of hazard identification and risk assessment at workplaces in a fuel and energy company applying the competence-based selection of an expert group.

Vectors of factor priorities were determined using the hierarchy analysis method. With the help of such priority vectors, global priorities of experts were ascertained, i.e. the advantages of inclusion in the group for hazard identification and risk assessment at workplaces.

The number of experts in the group (15 persons) was calculated – a boundary was found that determines the required number of experts to identify hazards and assess risks at workplaces ensuring sufficient reliability of the results.

The formed expert group identified hazards and assessed risks using the Fine – Kinney method at 6,105 workplaces of 24 branches of the fuel and energy company to determine the list of the PPE and wash-off agents taking into account the risk-oriented approach.

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