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Assessment of the Human Factor Influence on the Accident Initiation in the Oil and Gas Industry

The article describes main methods for assessing the influence of human factor on the accidents initiations in the oil and gas industry. According to the statistics, every second accident is due to the human fault as a result of human factor manifestation. Despite the large number of regulations and safety rules, there are still many accidents. This fact can be explained by the reason that these measures do not consider the biological nature of man.
The reasons leading a person to dangerous situations are considered in the article. Neuropsychological methods allow us to identify any health deviations, thereby eliminating the danger of human factor. The authors attempt to answer the question of how to ensure a high degree of safety at the complex and hazardous enterprises in the oil and gas industry. It is necessary to be able to assess the influence of human factor on the development of emergency situations. There are several methods to determine the influence of human factor on the accident occurrence, for example, SHEL, SHARP, THERP, HCR, SLIM, DNE, MAPPS methods, as well as an integrated indicator of human factor. However, these methods are not universal and perfect, therefore there is a need to do additional research in this area. The need of an integrated indicator for assessment of human factor influence on industrial risks is theoretically substantiated for the first time in this article. The need of development of the risk management algorithm in the oil and gas industry is scientifically proven, with the use of calculation method for assessing the human factor influence.

Keywords: human factor, emergency, accident, ergonomics, human reliability analysis, SHEL model, integrated indicator.

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Оценка влияния человеческого фактора на возникновение аварийных ситуаций в нефтегазовой отрасли

В статье рассмотрены основные методы оценки влияния человеческого фактора на риск развития аварийных ситуаций в нефтегазовой отрасли. По статистике, каждая вторая авария происходит вследствие проявления человеческого фактора. Несмотря на большое количество нормативных документов и правил безопасного труда, число аварийных ситуаций, обусловленных человеческим фактором, остается достаточно большим. Этот факт можно объяснить тем, что нормативные документы не учитывают природу человека.
В статье проанализированы причины, побуждающие человека к созданию опасных ситуаций. Нейропсихологические методы позволяют выявлять любые отклонения в состоянии здоровья, тем самым устраняя опасность проявления человеческого фактора. Авторы статьи пытаются ответить на вопрос, как обеспечить высокую степень безопасности на сложных и опасных предприятиях нефтегазовой отрасли.
По мнению авторов, для этого необходимо уметь оценивать влияние человеческого фактора на развитие аварийных ситуаций. Существует ряд методик, предназначенных для определения влияния человеческого фактора на возникновение аварий, например SHEL, SHARP, THERP, HCR, SLIM, DNE, MAPPS, а также интегральный критерий человеческого фактора. Данные методики не являются универсальными и совершенными, поэтому необходимо провести дополнительные исследования в этой области.
В статье впервые теоретически обоснована необходимость применения интегрального критерия для оценки влияния человеческого фактора на риск развития аварийных ситуаций на производстве. Научно обоснована

необходимость разработки алгоритма управления рисками на предприятиях нефтегазовой отрасли с применением расчетного метода оценки влияния человеческого фактора.

Ключевые слова: человеческий фактор, аварийная ситуация, эргономика, анализ надежности, модель SHEL, интегральный критерий.

A number of scientific works in our country and abroad are devoted to the problem of industrial injuries, its causes and consequences. Much attention is given to the human factor in its various manifestations. This problem is still relevant. Current statistical data on accidents in the oil and gas industry confirm that.

Existing control measures of the human factor influence have low efficiency because they practically do not consider the biological nature of man. Its logic differs fundamentally from the operating principles of mechanisms. The problem of reducing the risk of accidents and injuries in the enterprises of oil and gas industry based on the human factor is really important and relevant [1].

The aim of this work is to define a "human factor", to analyze its impact on the number of accidents, to propose a methodology for assessing and analyzing the level of psychosocial risks influence on workers in the oil and gas industry.

The most popular interpretation of the "human factor" term is a potential possibility of people taking the illogical and wrong decision in particular situation. Since the term "human factor" does not have exact definition, the authors of this article use it for erroneous actions of a man caused by the peculiarities of his biological nature and the conditions of his interaction with the environment.

Thus, a study of human factor deals with interaction of a man with machines, processes and environment, as well as with the interaction between people [2, 3].

The importance of considering human factor in the development of risk management methods for providing industrial safety in the oil and gas industry is confirmed by numerous accidents because of operator error. The study of professional competence and the knowledge of the safety fundamentals is not the most difficult, but absolutely necessary element in assessing the human factor [4].

It is also important to pay a special attention to the organization of the workplace, as it is a critical production factor that determines the condition and content of work of an employee [5, 6]. A poor attention in the casual, relaxed atmosphere can be a source of errors. The errors occurring during monotonous work almost never occur within the intense duty.

The errors of execution of certain actions can be associated with an unsatisfactory mental state of a person. Among different reasons of this state are the stress of dealing with the aftermath of a tragic event, tiredness, a beginning disease, insecurity in abilities or insufficient performance level for a complex activity, and lack of information support [7].

Ensuring high security in the complex oil and gas companies with hazardous production facilities is possible by combination of possibilities of modern safety systems and highly skilled personnel, psychologically prepared for a timely and adequate response to accident initiation or prevention of accident progression [8, 9].

RESEARCH METHODOLOGY

The human factor is a complex phenomenon that is rarely deeply analyzed, so it is difficult to assess the reliability of the employee, which is one of the most important characteristics of the human factor in the system "man – machine – environment".

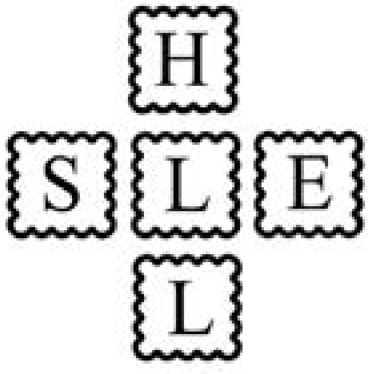

Fig. 1. The SHEL model [11]

The research of the influence of the psychological factors on operational safety, in particular on the accident rate, was made in one of the largest companies in petrochemical industry and gave interesting results. The hypothesis about positive relationship between favorable work conditions (i. e. motivational factor) and other factors affecting safety was confirmed on the basis of the survey data and the individual and functional analysis of the company's employees [10].

Nowadays, there are a number of methods assessing the influence of human factor on the accident progression, which are described below.

The SHEL model, firstly developed by Professor Elwyn Edwards in 1972, is used in the "Human Factors Training Manual" [11]. Schematically the SHEL model can be drawn in the form of separate blocks presenting different components of ergatic system (Fig. 1). It gives the possibility to visualize the need for mapping individual components.

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Федосов А.В., Хамитова А.Н., Абдрахманова К.Н., Абдрахманов Н.Х. Оценка влияния человеческого фактора на возникновение аварийных ситуаций в нефтегазовой отрасли. Территория «НЕФТЕГАЗ». 2018. № 1–2. С. 62–70. (Опубл. на англ.)

Table 1. Scale of the assessment of the integrated human factor

Grade	Motivation	Qualification	Function
5	Safety is the priority No. 1. Efficiency is achieved through safety	Sufficient for management in achieving of desired goal	Performing the work in accordance with the plan in compliance with all safety requirements
4	Safety and effectiveness are equivalent	Sufficient for independent problem solving	Working with minor deviations from the process regulations and the rules of safe operations
3	Choosing between efficiency and safety	Sufficient to conduct independent operations	Alternative choice: working with deviations from the plan or from the rules of safe operations
2	Efficiency is of the first order, security is secondary	Sufficient to perform the tasks with the help of colleagues	Performing work in accordance with the plan with significant deviations of safe operations rules
1	Safety is in the last place	Insufficient to perform the tasks	Ignoring safety requirements (systematic violations)

SHEL is an acronym from initial letters of modules: Software – installation (procedures, symbols); Hardware – object (machine); Environment – the environment where the elements of the system act; Liveware – subject (person). This model does not show the relationship between modules that are beyond the bounds, it is considered only as the supplement for understanding the human factor.

A person is in the center of the SHEL model. He is the most powerful and flexible component of the system. In production terms, a man is limited to the job requirements – the list of functions, most of which can be foreseen and regulated. Other modules of the model should be close to the center to prevent possible breakdowns in the system.

The SHARP (Systematic Human Action Reliability Procedure) technique is a procedure of system analysis of human errors, which has general steps for different methods: definition, division, performance, calculations, and documentation. The procedure consists of 7 steps and 2 phases to make a decision. The first two steps are performed by system analysts, the next two are made by specialists in the analysis of human factor, the last three steps are performed by joint efforts. The amount of work at each step depends on the type of technique used [12].

The THERP (Technique for Human Error Rate Prediction) methodology is also used to assess the role of human factor in safety control. It is a determination of significance of human errors in the technique. This technique is widespread as the most complete, allowing to make all steps of human errors analysis: identifying, modeling and quantifying human errors. The application of the methodology, the sequence of actions and conditions of data tables are given in the technical report [13].

The HCR (Human Cognitive Reliability) model considers the reliability of a person as a function of his abilities. It uses taxonomy by J. Rasmussen [14]. The dependence of the reliability of a man on the time is given as a specific formula. The method is often used for diagnostic purposes.

The SLIM (Success Likelihood Index Method) technique is a method of success probability indexes. It is connected with expert estimates and takes into account the psychological assessment. The method is based on the paired comparisons. It is comparing opinions of experts with each other, determining the factors, important for specific tasks, and their influence on the final probability of an error. The significance of each factor applies to the maximum and minimum values of the error. There is a computer version of SLIM-MAUD [15].

The DNE (Direct Numerical Estimation) methodology is based on the direct numerical evaluations, opinions, expert assessments. In this case, the probability of successful action of an operator is determined by the experts.

The MAPPS (Maintenance Personnel Performance Simulation) method is an approach of computer modeling. It is the expert system consisting of a set of rules, which are in the basis of decisions made by the operator during accidents [16, 17].

Currently, the technique of estimation of human factor by means of integrated indicator is the most modern and widely used.

Integrated criterion of human factor is assessed through motivation, qualifications and functions:

$$I = f(M, Q, F), \qquad (1)$$

where M – motivation; Q – qualification; F – performing functions.

Personal and organizational factors are determined by expert assessments according to the scale given in the table 1.

If we assume the factors influencing the level of accident and injury risk, then

$$I = F^{d1} Q^{d2} M^{d3}, \qquad (2)$$

where $d1$ – an empirical factor reflecting the degree of influence of motivation; $d2$ – an empirical factor reflecting efficiency of qualification; $d3$ – an empirical factor reflecting efficiency of influence functions.

The fulfillment of the condition is necessary: $d1 + d2 + d3 = 1$. The empirical coefficients are determined experimentally for each company (by questionnaire).

In 2014, the Russian Railways OJSC and the Klin Institute of Protection and Conditions of Labor developed a methodology to assess the human factor influence on injury production in the workplace and to determine the percentage of responsibility of people involved in this event [18].

The estimation algorithm is:

1) determination of a number of employees involved in an accident;

2) assessment of severity of violations of the industrial safety requirements;

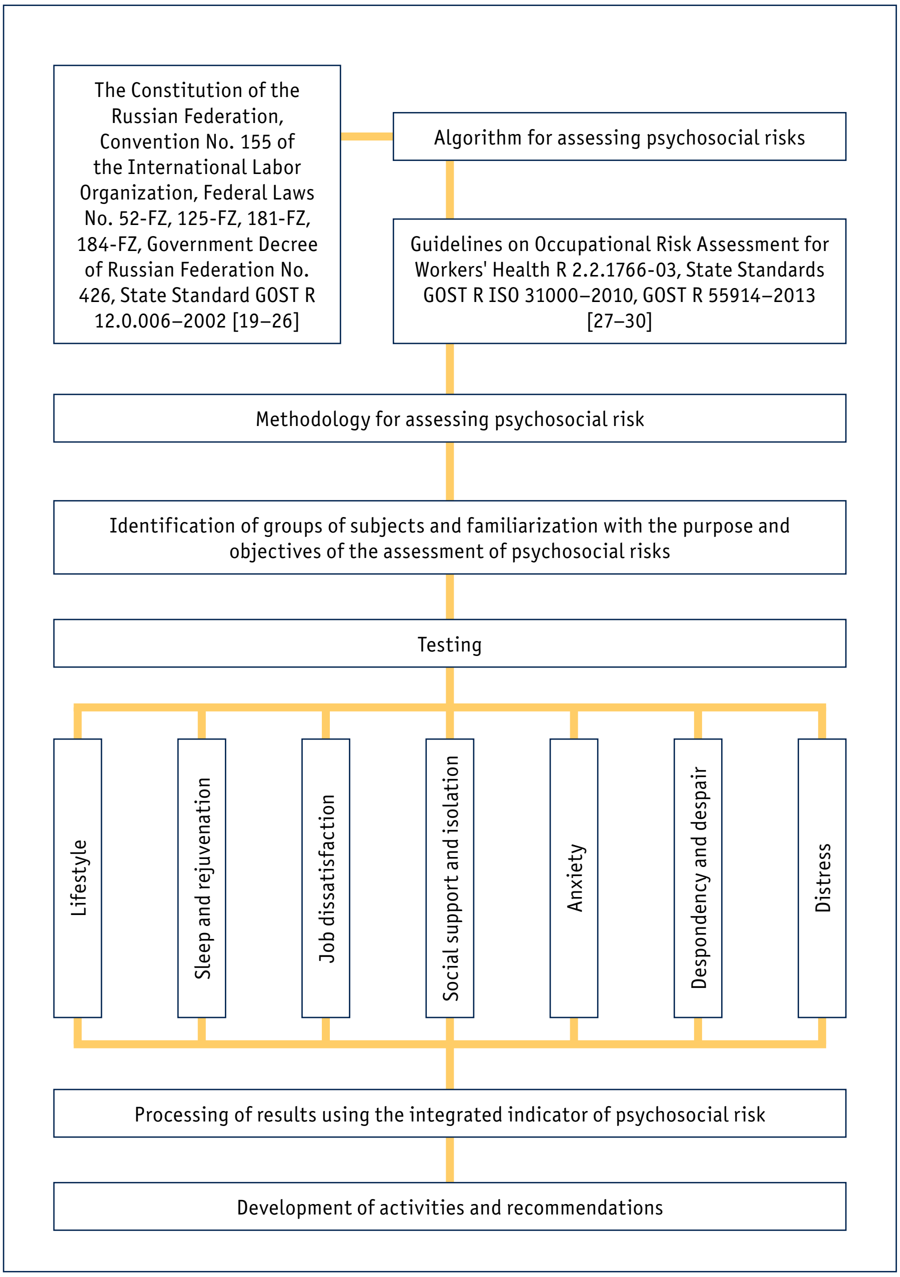

Fig. 2. Algorithm for assessing psychosocial risks

3) assessment of psychological and physiological causes of violations of the industrial safety requirements;
4) assessment of the level of employee responsibility by using matrix calculation of human factor influence on the initiation of an accident in the workplace;
5) results of evaluation of human factor influence on the initiation of an accident.
However, the above mentioned assessment methods of human factors influence are not precise enough and appropriate for every accident. Thus, the development of universal methodology is a relevant objective for increasing industrial safety and labor protection level [13].

OBTAINED DATA

Identified risk of injuries and accidents from human factors, assessment algorithms of production risk and management of human factor influence should be the main elements during the creation of methods reducing the risk. The methodology should include: assessment of actual risk in the production process; compliance assessment of actual human factor characteristic parameters; bringing the actual parameters of human factor characteristics to the targeted ones [16].
The authors of this article studied concepts of the psychosocial factor and risk, as well as its influence on health, safety and well-being of workers. These concepts should be used in assessment of labor conditions.
The psychosocial factor is the interaction between work content, its organization and management, and other external conditions, competencies and needs of workers.
Psychosocial risk is considered as a probability of dangerous effect of psychosocial factors on employee health through his perception, experience, and severity of disease state.
Risk assessment is a central element in the process of working conditions assessment. It provides information on nature and severity of a problem, psychosocial hazards, and also how they can influence employee health and the benefits of the organization. The authors propose an algorithm for assessing psychosocial risks (Fig. 2).
The methodology, including a questionnaire consisting of several general questions (sex, age, length of service) and 7 blocks of questions (lifestyle, sleep and rejuvenation, job dissatisfaction, social support and isolation, anxiety, despondency and despair, distress), was developed for realization of the algorithm.
Each block consists of 7 questions (49 questions in total) with four possible answers:
- definitely yes;
- more likely yes;
- more likely no;
- definitely no.

Each option of the answer is estimated from 1 to 4 points; the number of points of an answer is indicated in the test.
The primary integrated indicator is proposed to use for quantitative evaluation of the indicators by four-point scale. It is calculated by the formula:

$$\psi_n = \frac{(a - d) + (b - c)/2}{N}, \qquad (3)$$

Table 2. Class of working conditions, category of psychosocial risk and urgency of prophylactic measures

Class of working conditions according to [29]	Integrated risk index Ψ	Category of psychosocial risk	Urgency of the risk reduction measures
3.4	From –7 to –5.1	Very high risk	Works cannot be started or continued until the risk is reduced
3.3	From –5 to –2.6	High risk	Urgent risk reduction measures are required
3.2	From –2.5 to 0	Average (significant) risk	Risk reduction measures are required within the established time limit
3.1	From 0 to 2.5	Small (moderate) risk	Risk reduction measures are required
2	From 2.6 to 5	Negligible (tolerable) small risk	Measures are not required, but vulnerable persons need additional protection
1	From 5.1 to 7	There is no risk	Measures are not required

where *a* – the number of respondents who chose the "1 point" answer; *b* – "2 points"; *c* – "3 points"; *d* – "4 points"; *N* – the number of respondents.
Further, to calculate the integrated indicator of psychosocial risk (a separate category), it is necessary to sum up the primary integrated indicators of each question included in the block:

$$\Psi = \sum_{n} \psi. \quad (4)$$

The resulting integrated indicator of psychosocial risk is dimensionless, varies from -7 to +7 and corresponds to a certain class of working conditions and occupational risk categories (Table 2).
The final class of working conditions according to psychosocial factor of the production environment is calculated by the combination of working condition classes. As a result, the final category of the psychosocial risk influence is determined.

RESULTS AND DISCUSSION

The proposed methodology for psychosocial risks assessment was tested on employees of the refining company (Ufa, Russian Federation) and the petrochemical company (Ufa, Russian Federation).
The individual questionnaires were offered to participants of research. The integrated indices of psychosocial risks were calculated by formulae (1) and (2), based on the results of this test. The classes of working conditions and risk levels were determined. The results of the study are presented in the Tables 3–6.
The results of research show that in the refining company the level of psychosocial factor exposure is equal to class 3.1 of working conditions. The employees of this company are exposed to low risk.
Analysis of the individual characteristics having the smallest primary integrated indicator is given below. Thus, 82% of respondents gave a negative answer to the question "Do you use relaxation techniques?". 71% of respondents do not see career prospects. Similarly, 71% of respondents reject the possibility of psychologist counselling in difficult life situations. 85% of respondents do not feel the support of the labor organization in solving labor issues. 73% of respondents are afraid of losing their jobs, as well as 62% are constantly worried about the health and well-being of their relatives. 80% are aware of the influence of harmful production factors and worried about their health because of this.
It should be noted that all studied indices in the petrochemical company are lower than in the refining company. It means that employees of the petrochemical company are more exposed to the psychosocial factor.
The values of the "lifestyle", "job dissatisfaction", "social effects of isolation and support", "despondency" and "distress" indicators correspond to the class of working conditions 3.1, and the values of indicators "sleep" and "anxiety" correspond to the class of working conditions 3.2. There are one or more indicators with class 3.2, therefore the final class of working conditions for the psychosocial factor of employees in the production environment is equated to class 3.2. Thus, the risk is considered as average.
The individual characteristics with the smallest primary integrated indicator are given below. 70% of respondents pay attention to sports or physical activities only once a week or do not pay attention at all. 80% of respondents drink alcohol once a week or several times a month. 72% of respondents smoke more than two cigarettes every day. 40% of respondents drink several cups of coffee a day.
83% of participants feel tired not only in the evening but also in the morning after awakening. 69% of respondents fill sleepiness during the working day. 98% of respondents do not use relaxation practices to restore and relieve tension. 72% believe that they are not sufficiently involved in making decisions that affect their work. As well as 68% of respondents believe that they do not receive fair pay for their work, and 63% do not see opportunities for career growth.
97% of respondents are concerned about job loss, 51% have negative expectations from the future. 92% are aware of the impact of harmful production factors and are worried about their health on this ground. 45% of respondents noted strict terms of work execution and 60% noted that they are experiencing difficulties due to lack of time [5, 17].

CONCLUSIONS

The study has shown that the psychosocial factors of work environment are relevant for employees of the large industrial companies nowadays. Taking into account the evaluation results, the recommendations for providing safety and reducing the influence of psychosocial risks are proposed.

Table 3. Results of the psychosocial factor assessment of working environment for employees of the refining company (Ufa, Russian Federation)

Psychosocial risk	Value of the primary integrated risk indicator ψ_n						
	1	2	3	4	5	6	7
Lifestyle	0.20	0.07	0.69	0.46	0.13	0.70	0.37
Sleep/rejuvenation	0.54	0.50	0.59	0.50	–0.54	0.19	0.73
Job dissatisfaction	0.13	0.54	0.11	0.70	0.54	–0.24	0.41
Isolation	0.54	0.73	0.83	–0.29	–0.50	0.76	0.61
Anxiety	0.27	0.31	–0.31	0.23	0.34	–0.21	–0.46
Despondency	0.55	0.66	0.46	0.69	0.74	0.73	0.79
Distress	0.74	0.34	0.30	0.67	–0.04	0.30	0.14

Table 4. Correlation of the class of working conditions and the level of psychosocial risk at the refining company (Ufa, Russian Federation)

Psychosocial risk	Integrated risk indicator ψ_n	Class of working conditions	Category of psychosocial risk
Lifestyle	3.21	2	Negligible
Sleep/rejuvenation	2.60	2	Negligible
Job dissatisfaction	2.20	3.1	Small risk
Isolation	2.69	2	Negligible
Anxiety	0.17	3.1	Small risk
Despondency	4.61	2	Negligible
Distress	2.46	3.1	Small risk
The final class of working conditions (psychosocial factor)		3.1	Small risk

Table 5. Assessment results of psychosocial factor of working environment for employees of the petrochemical company (Ufa, Russian Federation)

Psychosocial risk	Integrated risk indicator ψ_n						
	1	2	3	4	5	6	7
Lifestyle	–0.36	1.00	0.63	0.86	–0.27	–0.47	–0.23
Sleep/rejuvenation	–0.50	0.20	0.50	–0.50	–1.00	0.17	0.34
Job dissatisfaction	–0.26	0.50	–0.50	0.50	0.30	–0.23	0.70
Isolation	0.50	0.11	0.30	–1.00	–0.51	0.36	0.50
Anxiety	0.09	0.10	–0.50	–0.03	0.07	0.37	–0.57
Despondency	0.39	0.43	0.09	0.23	0.04	0.17	0.20
Distress	0.69	0.03	–0.03	0.73	–0.01	–0.1	0.09

Table 6. Correlation of the class of working conditions and the level of psychosocial risk at the petrochemical company (Ufa, Russian Federation)

Psychosocial risk	Integrated risk indicator ψ_n	Class of working conditions	Category of psychosocial risk
Lifestyle	1.16	3.1	Small risk
Sleep/rejuvenation	–0.79	3.2	Average risk
Job dissatisfaction	1.02	3.1	Small risk
Isolation	0.26	3.1	Small risk
Anxiety	–0.49	3.2	Average risk
Despondency	1.54	3.1	Small risk
Distress	1.22	3.1	Small risk
The final class of working conditions (psychosocial factor)		3.2	Average risk

The most important condition of accident-free operation of potentially dangerous objects is to ensure the reliability of personnel and permissible level of influence of psychological factors. This totally depends on emotional, volitional, motivational, mental and other personal qualities that ensure accurate, error-free, adequate perception of the situation, timely and successful implementation of regulatory functions in different modes.

ВСЕРОССИЙСКАЯ
НЕДЕЛЯ ОХРАНЫ ТРУДА

ПРАВИТЕЛЬСТВО РОССИЙСКОЙ ФЕДЕРАЦИИ

МИНИСТЕРСТВО ТРУДА И СОЦИАЛЬНОЙ ЗАЩИТЫ РОССИЙСКОЙ ФЕДЕРАЦИИ

Ассоциация ЭТАЛОН

9–13 апреля 2018

ГЛАВНЫЙ МЕДИАЦЕНТР, **СОЧИ**

ГЛАВНОЕ СОБЫТИЕ ГОДА В СФЕРЕ ОХРАНЫ ТРУДА

// О НЕДЕЛЕ

«Впервые в нашей стране организована глобальная дискуссионная площадка, посвященная обеспечению безопасных условий труда.
Важно, что в обсуждении этих актуальных вопросов принимают участие не только российские специалисты, но и представители стран БРИКС и Евразийского экономического союза, Совета Европы, Международной организации труда и других авторитетных объединений.»

Д.А. Медведев, председатель Правительства Российской Федерации

«Комплексный подход, необходимый для решения существующих проблем в сфере охраны труда, может быть реализован только при условии концентрации усилий органов государственной власти всех уровней и специалистов по охране труда во всех организациях.»

М.А. Топилин, Министр труда и социальной защиты Российской Федерации

// ФОРМАТ

- Научно-практические конференции.
- Панельные дискуссии и круглые столы.
- Ведомственные и корпоративные совещания и заседания.
- Всероссийский съезд специалистов по охране труда.
- Семинары, курсы повышения квалификации, тренинги, экспертные консультации.
- Подведение итогов конкурсов и церемонии награждения, презентации.

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