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Assessment of operational risks in the oil and gas industry

Ocena ryzyka operacyjnego w przemyśle naftowym i gazowym

Vadim O. Bogopolsky, Azad A. Bagirov, Magomed M. Shirinov

Azerbaijan State Oil and Industry University

ABSTRACT: The article provides an overview of the oil and gas extraction industry, recognized as one of the most environmentally hazardous industries globally. It is marked by a high risk of explosions and fires at industrial facilities. Chemical reagents used in drilling wells, oil production and preparation, as well as the extracted hydrocarbons and their impurities, pose harmful threats to flora, fauna, and humans. Additionally, oil and gas production is dangerous due to a high rate of accidents, as primary production processes occur under high pressure and in aggressive environments. The main task of risk identification and assessment is to use risk as a basis for prioritizing actions and managing an inspection program, where equipment and types of work being inspected are ranked according to the degree of risk. In almost every situation, once a risk is identified, there are alternative ways to mitigate it. The analysis and assessment of the state of occupational injuries are essential for the successful operation of any system, including occupational safety. The article examines objective qualitative and quantitative indicators that characterize the state of occupational safety and the safety or danger of production. It highlights that an important aspect of ensuring safety in the operation of oil and gas production and refining facilities involves identifying, analyzing, and controlling the risks of large-scale accidents. To achieve this, it is necessary to implement control measures and certify all possible risks in project documents to prevent them. This task is relevant and specific to each enterprise in the oil and gas industry.

Key words: production risks, risk assessment, environmental system reliability, risk management methods, risk event.

STRESZCZENIE: W artykule dokonano analizy przemysłu wydobywczego ropy naftowej i gazu ziemnego, uznawanego za jedną z najbardziej szkodliwych dla środowiska gałęzi przemysłu na świecie. Przemysł ten charakteryzuje wysokie ryzyko możliwości zaistnienia eksplozji i pożarów w obiektach przemysłowych. Odczynniki chemiczne stosowane w odwiertach, produkcji i przetwarzaniu ropy naftowej, a także wydobyte węglowodory i występujące w nich zanieczyszczenia stanowią zagrożenie dla flory, fauny i ludzi. Ponadto wydobycie ropy naftowej i gazu ziemnego jest niebezpieczne ze względu na wysoki odsetek wypadków, ponieważ podstawowe procesy produkcyjne zachodzą pod wysokim ciśnieniem i w agresywnym środowisku. Głównym zadaniem identyfikacji i oceny ryzyka jest wykorzystanie go jako podstawy do ustalania priorytetów działań i zarządzania programem inspekcji, w którym sprzęt i rodzaje kontrolowanych prac są uszeregowane według stopnia ryzyka. W niemal każdej sytuacji, po zidentyfikowaniu ryzyka, można je ograniczyć na różne sposoby. Analiza i ocena stanu wypadków przy pracy ma zasadnicze znaczenie dla pomyślnego funkcjonowania każdego systemu, w tym BHP. W artykule przeanalizowano obiektywne wskaźniki jakościowe i ilościowe, które charakteryzują stan bezpieczeństwa pracy oraz poziom bezpieczeństwa lub zagrożenia związanego z produkcją. Podkreślono, że ważnym aspektem zapewnienia bezpieczeństwa w eksploatacji instalacji do produkcji i rafinacji ropy naftowej i gazu jest identyfikacja, analiza i kontrola ryzyka poważnych wypadków. Aby to osiągnąć, konieczne jest wdrożenie środków kontroli i określenie wszystkich możliwych zagrożeń w dokumentach projektowych, aby im zapobiec. Jest to istotne zadanie, które należy przeprowadzić odrębnie w każdym przedsiębiorstwie w branży naftowo-gazowej.

Słowa kluczowe: ryzyko produkcyjne, ocena ryzyka, niezawodność systemu środowiskowego, metody zarządzania ryzykiem, zdarzenie ryzyka.

Corresponding author: V.O. Bogopolsky, e-mail: *vadim46.46@mail.ru*

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Introduction

The oil and gas industry as a system is characterized by a number of specific features that distinguish it from other industries.

Oil and gas production facilities, even when located in several regions, can form a single technological system, creating an interconnected infrastructure. This interconnectedness makes their influence on each other more complex and diverse.

With the growth of global energy demand, oil and gas companies face both numerous opportunities and certain risks in all segments of the industry: exploration, production, processing, transportation, and marketing of oil and gas products.

The gas and oil industries encompass companies engaged in these activities, as well as those providing related and petrochemical enterprises (Tasmukhanova, 2011).

The production risks inherent in the oil and gas industry enterprises are primarily determined by the nature of their activities. Analyzing and assessing occupational injuries are necessary conditions for the successful operation of any system, including occupational safety.

It is crucial for evaluating the effectiveness of management in achieving goals and for planning preventive measures.

This can only be accomplished through a set of targets and criteria, their numerical evaluation, and comparison with established or initial values (Abdrakhmanov et al., 2015).

Determining objective quantitative indicators that characterize the state (level) of occupational safety, safety or danger of production, and the reliability of the human environment (industrial, natural, social) is both relevant and specific for each enterprise in the oil and gas industry.

At the same time, common approaches to solving these issues should be adopted.

Risk assessment should be an integral part of a systematic approach to the implementation of the labor process. It serves as a method of managing the safety of technological processes and production areas and is a practical means of implementing measures to prevent or reduce industrial hazards.

Stages of industrial safety risk management

Risk management can be divided into several main stages:

1. determining the risk and assessing its probability;
2. assessing the scale of the consequences, determining the maximum possible damage;
3. selecting methods and tools to manage the identified risk;
4. developing a risk strategy to mitigate the risk and minimize potential negative consequences;
5. implementing the risk strategy;
6. evaluating the results obtained and making necessary adjustments to the risk strategy.

An analysis of modern methods of risk assessment and decision-making in conditions of uncertainty shows that different authors have varying interpretations of the term “risk”.

The concept of risk is often associated with the probability of an undesirable event (Figure 1).

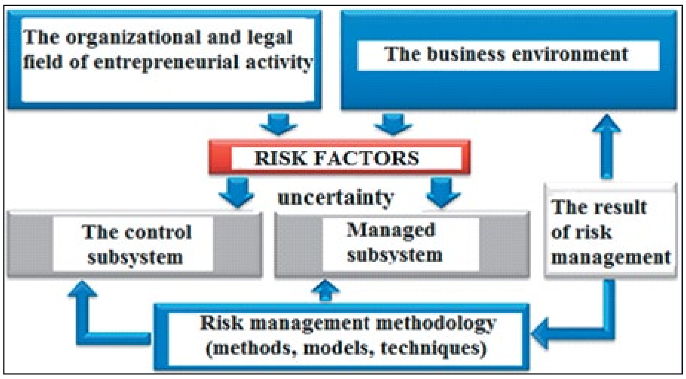

Figure 1. Generalized scheme of the risk management system (RMS)

Rysunek 1. Uogólniony schemat systemu zarządzania ryzykiem (RMS)

Figure 1 shows a model representing ways, methods, and techniques of working with risk, i.e. risk management system (RMS). In practice, there are two particular variants of the risk management system:

1. organization of RMS by establishing a specialized unit (*dedicated model*);
2. construction of the RMS model by distributing risk management functions among operating divisions (*distributed model*).

Organizing risk management according to the dedicated model involves creating a structure with at least three functional directions:

1. analytical – responsible for the analysis, assessment, and monitoring of threats;
2. development of anti-risk measures;
3. administrative.

The RMS organization based on the distributed model is less capital-intensive.

In this model, responsibility matrices are created to assign risk management duties to each business unit (Sultanov).

As for practical application, it should be noted that the methodological apparatus of risk analysis and assessment is already used in the oil and gas industry in the following forms:

- studying existing methods of analyzing occupational injuries;
- selecting and improving methods for studying occupational injuries;

- identifying traumatic factors affecting occupational injury indicators;
- studying existing methods for determining production risks;
- justifying the need to identify production risks and studying these risks within the structural unit of the enterprise;
- developing measures to prevent occupational injuries.

The following types of risk determination are used:
- risky event – a combination of the probability of its occurrence and the consequences of the risk;
- risk analysis – the process of systematically processing data to identify hazards and assess risk;
- risk assessment – the process of analyzing and measuring risk.

Risk management methods and tools

Currently, the main risk management methods and relevant risk management tools include:
- risk aversion (rejection of extremely risky activities);
- risk reduction (prevention or diversification);
- risk transfer (outsourcing or insuring expensive risky functions);
- acceptance (forming stocks or reserves).

For example, the laws of some states define risk as follows: "risk is the degree of probability of a certain negative event that may occur on the territory of a country at a certain time or under certain conditions of an object of increased danger and/or beyond its borders".

This definition of risk boils down to determining the probability of an accident occurring at a facility over a certain period of time, typically one year.

Risks can be assessed both qualitatively and quantitatively.

Qualitative methods of risk assessment in the oil and gas industry

Below are some methods of risk assessment in the oil and gas industry.

One of the effective methods of qualitative risk analysis is the use of various kinds of diagrams. An example is the Ishikawa diagram, which allows for analyzing the systemic causes of risk situations (Maksimenko, 2017).

When analyzing risks, Goldstein and Romanov (2018) resort to a systematic approach. This method helps determine the order of actions and ways of responding, identify bottlenecks that can be addressed to improve the occupational safety system.

In the qualitative risk analysis of the oil and gas industry, expert assessments are also utilized. Thus, using the constructed matrix, the factors that most strongly affect the state of the production risk management system are identified, which means that the selected factors can be influenced in order to reduce the number of occupational injuries (Goldstein and Romanov, 2018).

Quantitative methods for assessing risks of the oil and gas industry

Statistical methods can be used to quantify risk (Artyukhov, 2009; Akbarova, 2019).

For analyzing occupational injuries, many enterprises use several calculated indicators (Ispanbetov, 2014) such as:
- injury frequency coefficient (the number of accidents per 1,000 employees);
- injury severity coefficient, which expresses the number of days of disability per injury;
- total injury rate showing the total number of days of disability 1,000 employees;
- accident disability and fatality coefficient (percent);
- number of victims per 1,000 employees.

These indicators enable the assessment of injuries and support the adoption of objective and balanced management decisions in industrial safety regulation.

Various mathematical models are used in the quantitative analysis of enterprise risks.

The total risk of occupational injuries can be considered as an additive form of several components, namely:

$$R = k_A R_A + k_R R_R + k_T R_T + k_C R_C \qquad (1)$$

where:
k_A, k_R, k_T, k_C – weight coefficients,
R_A – risk of accidents,
R_R – risk due to work, including high-risk work,
R_T – risk due to adverse working conditions,
R_C – risk due to the absence or non-compliance with personal protective equipment.

To unify the assessment, a point system is used where the risk from each factor is assessed on a scale from 1 to 25.

The total risk can thus be estimated from 4 to 100 points.

To formalize the risk (R), a model is widely used that connects the probability (P) of the occurrence of a negative event A (accident, catastrophe) with the probable magnitude of the possible consequences (W) resulting from this event, namely:

$$R(A) = P(A) \cdot W(A) \qquad (2)$$

The probability $P(A)$ present in this model numerically expresses the measure of the possibility of a particular negative event A associated with an uncertain situation. The probable magnitude of the expected consequences $W(A)$ as a result of the implementation of a negative event A depends not only on possible losses (number of deaths, injuries, material losses), but also on the degree of vulnerability of the object to event A, that is:

$$W(A) = V(A) \cdot U(A) \tag{3}$$

where:

$W(A)$ – probable magnitude of the possible consequences of event A,

$V(A)$ – degree of vulnerability of the object to event A,

$U(A)$ – conditional total damage resulting from event A.

Thus, substituting expression (3) into formula (2), we obtain a model for determining the level of risk:

$$R(A) = P(A) \cdot V(A) \cdot U(A) \tag{4}$$

where:

$R(A)$ – risk (of a negative event A),

$P(A)$ – probability that a certain risk exists,

$V(A)$ – probability that the risk can be avoided,

$U(A)$ – measure that determines the severity of the risk.

The values of P and U can be objectively chosen based on statistical data.

Thus, formula (4) is common to all types of risk characterized by the scale of manifestation.

However, in each specific case, additional research may be required for its practical use (Andreev et al., 2007).

The classification of project risks by is based on the division of risks into general and specific, as well as the allocation of individual types of risk according to the stages of implementation of an oil and gas project: prospecting, exploration, field development, transportation and processing of oil, gas, and condensate.

The general classification of project risks in the oil and gas industry proposed by Andreev et al. (2007) on five grounds effectively summarizes and deepens previous research experience in this area.

In addition, the introduction of such specific risks unique to the oil and gas industry, such as risks associated with the inaccurate determination of geological and field characteristics of the development object, allows for a more thorough analysis of investment projects (Khazeev, 2015).

In general, the criteria for determining the degree of risk should include:

- analysis of legislation,
- working time schedule,
- contact with regulatory documents related to hazardous equipment,
- compliance with fire safety standards,
- adherence to environmental protection rules,
- analysis of injuries and diseases at work (over the past 5 years),
- existing risk factors and their measurement (workplace certification data),
- existing employee complaints,
- documentation of information on the service life and degree of wear of technological equipment (results of various inspections),
- information on staff qualifications and motivation (Lapteva et al., 2011; Gallyamova, 2016).

Risks can lead to the following consequences:

- a large number of injuries or deaths,
- significant financial losses,
- environmental disasters or other negative socio-cultural consequences (Imasheva, 2013; Tymul, 2021).

These events can negatively impact the company's reputation at both the international and national levels.

The main task of risk identification and assessment is to use risk as a basis for prioritizing actions and managing an inspection program in which the equipment being checked is ranked according to the degree of risk. In almost every situation, once the risk is identified, there are alternative ways to reduce it.

On the other hand, almost all major business losses result from a misunderstanding of or mismanagement of risks.

Risk analysis and assessment of hazardous production facilities

Most of the technical means, buildings, and structures at the facilities of the fuel and energy complex have exceeded their expected service life, are obsolete, and have practically exhausted their resource by 60–80%.

This can be confirmed by the recent increase in accidents and man-made disasters on offshore platforms (Figure 2), at oil refineries (Figure 3), at fuel depots, oil depots, and other hazardous production facilities (Aliyev, 2017).

These issues are generally due to gross violations and non-compliance with industrial safety requirements both during the design process and during operation.

Given the high aggressiveness of the products produced at oil and gas production and refining enterprises, work on risk analysis and assessment is becoming increasingly relevant.

Figure 2 shows an accident that occurred in 2005 on the Thunder Horse PDQ semi-submersible drilling rig platform due to Hurricane Dennis. The accident was caused by flooding of the underwater balancer tanks resulting from broken welds in the pipes connecting these tanks. All the cracks were along

Figure 2. Offshore drilling rig after an accident in 2005
Rysunek 2. Morska platforma wiertnicza po wypadku w 2005 r.

the welds, indicating poor quality workmanship. However, the registry commission (maritime registry), which had inspected the platform shortly before the incident, found no breach of structural integrity and recommended permanent repairs with the issuance of an official PDQ suitability certificate. This accident was attributed to the negligence on the part of welders, inspectors, ultra-sonic diagnostics specialists, and controlling state authorities.

Generally, such incidents are due to gross violations and non-compliance with industrial safety requirements both during design and operation phases.

Figure 3 shows an accident at an oil refinery in Russia. The catalyst for such accidents is most often insufficient level of responsibility and qualification of managers and executives, ineffective operation of production control services, erroneous actions by employees during emergency situations, and neglect of safety techniques.

Figure 3. Accident at oil refining facilities
Rysunek 3. Wypadek w rafinerii ropy naftowej

Due to the highly aggressive nature of the products produced at oil and gas production and refining enterprises, risk analysis and assessment are becoming increasingly important.

Conclusions

This article considers a general systematic approach that allows for the generalization of various risk analysis methods in the oil and gas industry. It is demonstrated that each method has its own set of advantages and disadvantages, making it impossible to single out a single superior method. Depending on the situation, different methods can be used, combined, and their compared to achieve the best outcomes.

It is shown that an important aspect of ensuring safety in the construction and operation of oil and gas production and refining facilities is the large-scale accident risk identification, analysis, and control. To achieve this, it is necessary to implement control measures and document all possible risks in project documents to prevent them.

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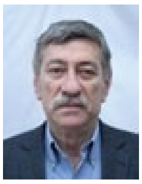
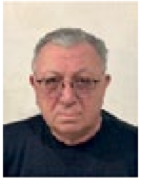


Vadim Oskarovic BOGOPOLSKY, Ph.D.
Assistant professor at the Department of Oil and Gas Engineering
Azerbaijan State Oil and Industry University
16/21 Azadliq Ave., AZ1010 Baku, Azerbaijan
E-mail: *vadim46.46@mail.ru*



Azad Adkham BAGIROV, Ph.D.
Assistant professor at the Department of Oil and Gas Engineering
Azerbaijan State Oil and Industry University
16/21 Azadliq Ave., AZ1010 Baku, Azerbaijan
E-mail: *azad-baqirov@mail.ru*

Magomed Makhmud SHIRINOV, Ph.D.
Assistant professor at the Department of Oil and Gas Engineering
Azerbaijan State Oil and Industry University
16/21 Azadliq Ave., Baku, Azerbaijan
E-mail: *shirinov46@mail.ru*