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SCIENTIFIC AND METHODOLOGICAL APPROACHES TO ASSESSING THE SAFETY OF OIL PRODUCTION COMPLEXES AS POTENTIALLY DANGEROUS OBJECTS

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Abstract

The purpose of the article is to determine the optimal approach to assessing the risk of oil production objects as potentially dangerous objects. The current regulatory documents and international standards governing the process of risk assessment in the event of an emergency at oil production facilities became the methodological basis of the studies. The scientific and methodological basis of research is a modified deterministic and probabilistic approach to determining the risk of an emergency using fuzzy logic methods in the form of neural networks. The significance of anthropogenic disturbances of the natural environment at all levels was assessed according to the following parameters: spatial scale; time scale; intensity. Comparison of the values of the degree of impact for each parameter was evaluated by a point system according to the developed criteria. A comprehensive (integral) assessment of the load on individual components of the natural environment from different sources of impacts was set at the level of 6 points, which is identified as an impact of low significance. The studies were carried out on the example of consequences of emergency situations on the territory of the Sumy region for the period 2017–2021. The article gives recommendations of an organizational and technological nature to eliminate or reduce the degree of risk from emergencies associated with an oil spill.

Key words: environmental safety, risk, hazard assessment, probabilistic approach, deterministic approach, fuzzy logic, oil production, accidents.

Problem statement

In the field of modeling and assessing the safety (risk) of potentially hazardous facilities and industries, there are two approaches, which have been developed and applied in the world. They are known as deterministic (zero risk) and probabilistic (non-zero risk) approaches, which contributed to the expansion of ideas about the relativity of safety and the birth of the concept of "acceptable" risk.

The probabilistic approach is based on the knowledge about the dangers of systems and bringing the latest achievements to make the tasks of risk management systematic. The disadvantages of these methods are eliminated by developing and applying active approaches in the analysis and assessment of safety, which include the logical and probabilistic method for establishing the probability of incidents.

If it is possible to describe the properties, preconditions and relationships in the form of comparable parameters and functions, then the measure of the certainty of the occurrence of an incident can be obtained in the form of the exact measure - the measure of necessity. If the initial data are presented as random variables and processes with the complete set of all preconditions and their relationships identified at the same time, and the conditions for all random variables are taken into account (which is unattainable in practice), then the measure of certainty of the incident can be obtained in the form of a probabilistic measure. If the initial data on the systems are vague and inaccurate (which often happens in practice), then the measure of certainty of the occurrence of an incident can be obtained in the form of a possible measure.

The construction of a complete group of sources and receivers, hazard factors and channels are common for the methodology of deterministic and probabilistic safety assessment. Such conditions as the analysis of an incomplete group according to the selected "defining" elements, the method of extreme indicators and extreme situations and the solution methods for the maximum design situation are typical for the deterministic safety assessment methodology. The methodology of probabilistic safety assessment provides for building a logical model of the most undesirable outcome based on a logical model of failure of a potentially dangerous object (determining events); determination of the probabilistic model of the most undesirable outcome according to the forms and rules of the transition; calculation of the values of the probability measure of the most undesirable outcome.

The result of the first methodology is the project of a safe complex technical system with selected extreme indicators concerning the most undesirable outcome. The result of the second methodology is the design of a safe complex technical system, taking into account the identified values of connections; frequency or hypothetical substantiation of the risk of damage and the strategy of the balance of indicators «efficiency – safety – cost».

1. There are statistics for active failure or data to substantiate the characteristics of the hypothetical probability functions.

2. There are difficulties in defining and describing the complete group of situations in the system and, as a result, the assessment for extreme situations (maximum design accidents) may be incomplete and (or) not sufficiently reliable.

3. The inevitability of the presence of approximate and (or) unreliable data about the object, unregulated factors and their propagation is recognized, nevertheless, there are no methods that allow

a) to take inaccurate information into account and

b) to calculate safety and risk indicators.

4. There are no general models for the group of indicators such as “efficiency – safety – cost: in order to determine the “acceptable” risk and (or) define their optimal balance.

5. The impossibility within the framework of these approaches of non-static finding of measures of certainty (uncertainty) of the incident occurrence and the most undesirable outcome in the system.

Analysis of the recent researches and publications

According to [1] such critically important objects (CIOs) as oil refineries, petroleum organic synthesis plants, petrochemical plants and shale processing plants belong to the group of chemically dangerous objects from potentially hazardous and critically important objects (PHCIO). However, fire and explosion hazard and fire hazard objects include in particular oil related objects as follows enterprises of the oil industry, gas industry enterprises, shale industry enterprises, gas and oil wells, offshore oil platforms, enterprises of the oil refining industry, petrochemical industry enterprises, enterprises of the gas processing industry, stocks of oil and liquid petroleum products, offshore platforms, semi-submerged and underwater oil storage facilities, oil pipelines, gas pipelines. Three groups of calculation methods with the necessary databases should be included in the tools for the analysis of the PHCIO:

1) methods for assessing processes and ways occurrence of adverse events (accidents, natural disasters and disasters);

2) methods describing the consequences of adverse events, such as the release, behavior and spread in the environment of dangerous substances and the mechanisms of damage to these substances of the human body;

3) methods for assessing economic loss and optimizing the use of funds to prevent or mitigate the effects of adverse events.

For functioning pipelines the main factors affecting the environment are product leaks (gas, oil, ammonia, etc.) and extreme emergencies (explosions, ruptures due to land subsidence, stress corrosion cracking), which pose a danger to the environment as a whole and to human life and health, respectively. According to the authors [2] there is no clear methodology for ensuring the safety of pipeline networks in Ukraine. When designing, according to existing regulations, if the project meets all current requirements, a separate safety analysis and a thorough risk analysis with an assessment of the number of possible failures and forecasts of their consequences are not carried out. This practice leads to the fact that we hear more and more about serious accidents on pipelines transport.

Accidents of process pipelines are often accompanied by the release of flammable substances to the atmosphere, which is caused by construction defects; pipe corrosion and unauthorized cuts.

On the basis of the conducted experiments relating to the study on the influence of the properties of solid surfaces on the change in the liquid spillage area, the following result was received. During subsequent experiments, the area of the spilled liquid does not increase in a straight line with the same increase in the volume of the liquid, but changes taking into account the surface phenomena based on the interaction of the liquid and the solid. Such phenomena such as wetting and adhesion, close to adsorption, are determined by the intensity of interaction between the molecules of various substances.

The main difficulty of risk assessment is heterogeneity of the input information about current state of the pipeline segments based on the results of its examination, information about operation and maintenance, the influence of external factors. Furthermore, risk assessment is complicated by the dynamic character of the risk factors determining the current level of risk along the trunk pipeline in general [3]. In such circumstances, most of deterministic and statistical models for risk assessment don’t reflect the current risk condition of hazardous pipeline.

Risk assessment is based on the preliminary risk prediction analysis using deterministic and probabilistic models of emissions of hazardous substances, followed by the construction of a potentially dangerous zone at the specific facility while designing. In general, it should be noted that the use of various methodological approaches to assessing technical risk at the stage of declaring the industrial safety is restrained due to the impossibility of assessing the reliability of the obtained results on the forecast of emergencies because of the lack of operational monitoring of non-stationary risks. Moreover, the traditional idea of the frequency of occurrence and the development of emergencies in terms of stationary processes with a normal distribution is considered to be incorrect [4].

The theory of fuzzy logic will allow avoiding disadvantages of deterministic and probabilistic approaches, which are mentioned above, and therefore, it is proposed to use fuzzy neural (hybrid) networks to assess the current level of risk. The use of linguistic variables in the assessment of uncertain input data in the establishment of risk factors will allow us to identify all indicators of these risk factors.

Statement of the problem and its solution. Approaches to the methodology

There are different approaches to the risk assessment declared in regulatory documents at the level of individual countries (USA) and the European Union, there are also international standards and guidelines for determining the degree of safety of technological objects for the environment. Figure 1 demonstrates methods for risk evaluation after spills.

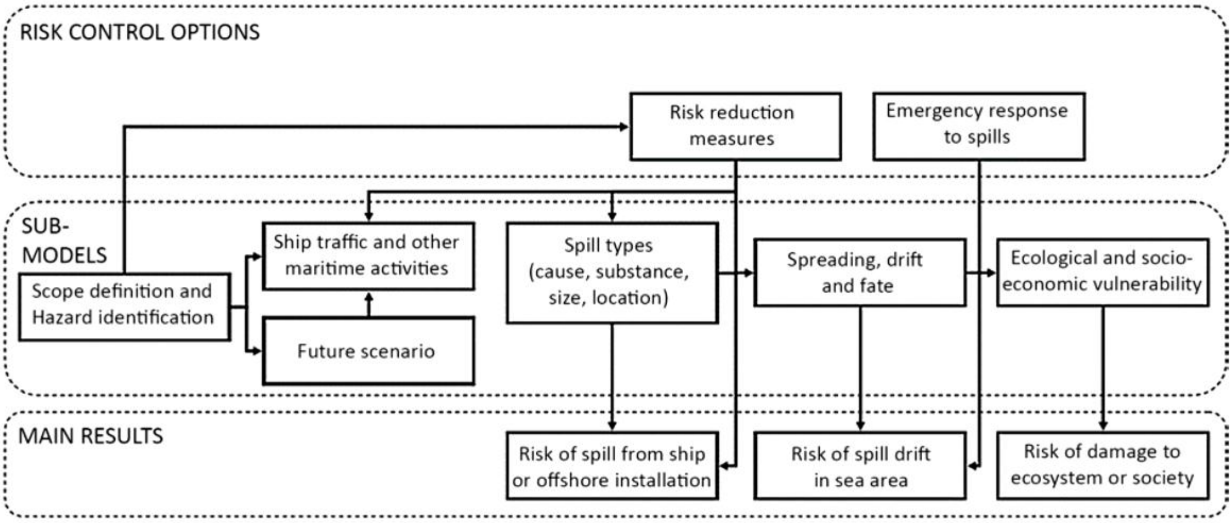

Figure 1 – Integrated strategic risk analysis methods

Risk evaluation and management include such steps:

- Description of project;
- Hazard identification;
- Identification of consequences;
- Magnitude of consequences;
- Probability of consequences;
- Risk management.

The ISO 31000:2018 risk management process is comprised of a number of stages, as shown in Figure 2.

There are five main stages in the generic risk management process: Stage 1 “Establishing the context”, Stage 2 “Risk identification”, Stage 3 “Risk analysis”, Stage 4 “Risk evaluation” and Stage 5 “Risk treatment”. Steps ii) to iv), i.e. risk identification, analysis, and evaluation, are usually referred to as risk assessment [5].

Stage 3 “Risk analysis” consist of four steps:

Step 1 “Estimating the probability of the event occurrence”;

Step 2 “Estimating the severity of the consequences in case of event occurrence”;

Step 3 “Assessing the strength of the evidence for the probability and consequence estimation”;

Step 4 “Combining probability, consequence, and strength of evidence in a risk scale”.

In the functional diagram of the risk analysis methodology (Figure 3), a distinctive feature (in comparison with already known schemes) is the presence of a module for determining the relative risk indicator, which allows taking into account the time change in the conditions of the occurrence and development of emergencies, and a module of risk minimization control, which allows managing an acceptable risk value according to the quantitative criterion of early recognition of a pre-emergency situation [6]. The system risk assessment, as well as the impact damage assessment, is a complex hierarchical system with non-stationary technological processes occurring at various stages of the implementation of design solutions in different time intervals [7].

Different software is highly used for risk assessment, as it is indicated in Table 1, taking into account three steps of risk assessment.

A perspective approach to risk assessment can be a modified method of deterministic risk assessment that uses risk indices (index of state I), as well as fuzzy logic methods to combine initial quantitative and qualitative (expert) information about the state of a potentially dangerous object. This methodology corresponds to the recommendations of IEC 31010:2019. “Risk Management – Risk Assessment Methods. NEQ” [9]. In practice deterministic scores of the state were presented in the form of risk indices and used as data to assess the probability of accidents and the development of a probabilistic risk assessment methodology. The studied database, obtained due to examinations and checks, as well as the collection of the results of expert assessments, is the main source of information for the procedure to assess the probability of an emergency. The proposed method provides for combining the initial quantitative and qualitative (expert) information about various damages.

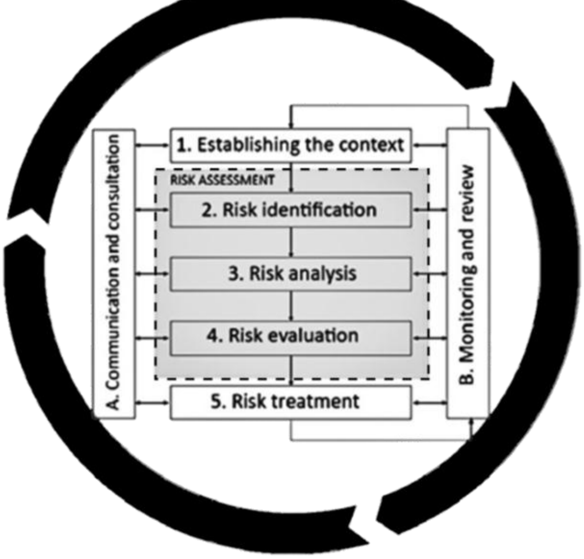

Figure 2 – The Risk Management Process as described by ISO 31000:2018

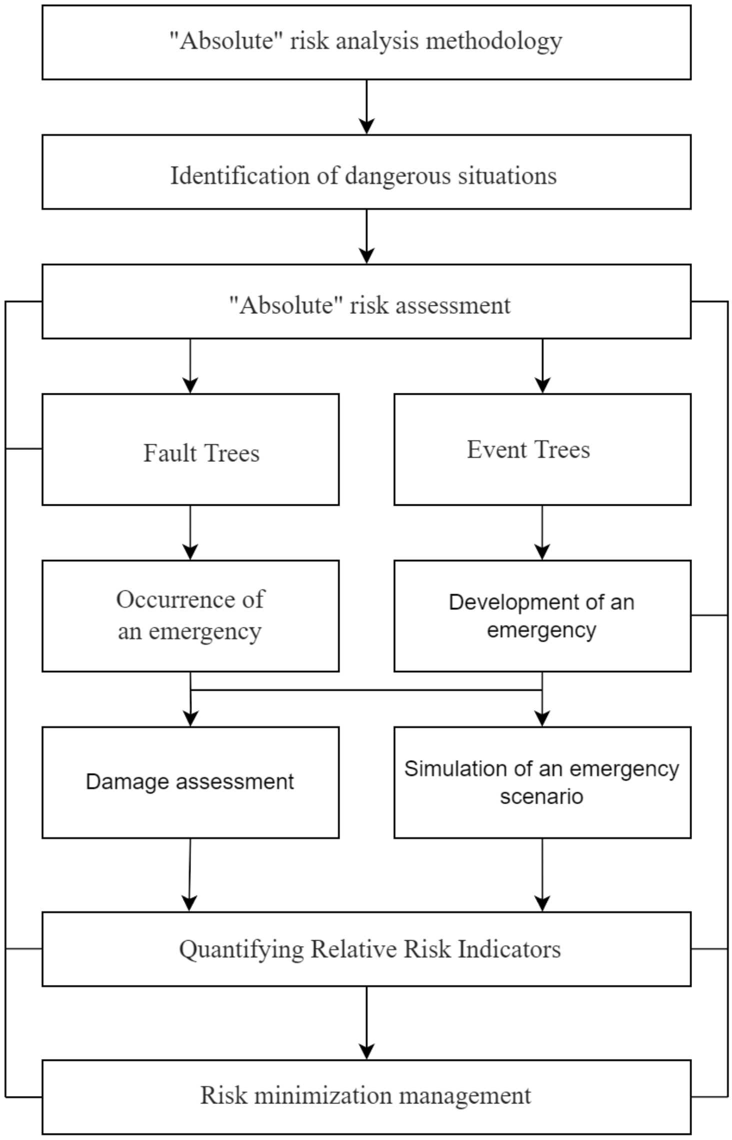

Figure 3 – Functional diagram of building a system of analysis of “technical risk” [8]

Table 1 – Applicability (Strongly applicable) of the OpenRisk Toolbox*

Screening risk management process (stage)	***Basic***	***Extended***	***Intermittent***	***Strategic***
Risk identification	none	Delphi	ERC-M BowTie FRAM	Delphi
Risk analysis	AISyRisk MarinRisk RiskData Hub KPIs SoE	KPIs, SoE	PAWSA ADSAM-C/G SeaTrack Web NG-SRW ERSP Calculator EBSP Calculator EDSP Calculator SoE	PAWSA, SBOSRT ISRAM SoE
Risk evaluation	KPIs ALARP	KPIs RM-PCDS ALARP	RM-PCDS ALARP CBA	RM-PCDS ALARP CBA

*MarinRisk – Marin Risk Index; KPIs – Key Performance Indicators; SoE – Strength of Evidence Assessment Schemes;
ALARP – As Low as Reasonably Practicable Principle; Delphi – Delphi Method; RM-PCDS – Risk Matrices and Probability Consequence Diagrams;
ERC-M – Maritime Event Risk Classification Method; BowTie – BowTie Method; FRAM – Functional Resonance Analysis Method;
PAWSA – Ports and Waterways Safety Assessment; ADSAM-C/G – Accidental Damage and Spill Assessment Model for Collision & Grounding;
NG-SRW – Next Generation Smart Response Web; ERSP Calculator, EBSP Calculator, EDSP Calculator – Response System Planning Calculators;
CBA – Cost-Benefit Analysis; SBOSRT – Spatial Bayesian Oil Spill Risk Tool; ISRAM – Integrated Strategic Risk Analysis Methods

To solve the task of determining the safety of the oil production process and subsequent operations with the extracted raw materials, it is advisable to use a fuzzy neural hybrid network, which usually consists of four layers: the fuzzification layer of input variables, the layer of aggregation of values of condition activation, the layer of aggregation of fuzzy rules and the output layer. In this case, the fuzzy neural network operates in a standard way based on real numbers. Only the interpretation of the results is fuzzy. A fuzzy neural hybrid network is a neural network with crisp signals, weights, and an activation function, but with the combination of x, w, and p2 using the t-norm, t-conorm, or some other continuous operations. Inputs, outputs and weights of a fuzzy neural network are real numbers belonging to the segment [0, 1]. A fuzzy neural network is usually called a clear neural network, which is built on the basis of a multi-layer architecture using "AND", "OR" neurons.

Impact assessment in case of emergencies (risk analysis)

According to the State Ecological Inspectorate in Sumy region from 2017 to 2021 in Okhtyrka there were 17 emergency oil spills due to depressurization in oil pipelines, oil collectors or due to the discharge line of the well. The total area of soil pollution resulted from oil was 39.899 m^2, moreover, the most large-scale and unprofitable emergency situation with the polluted area of 11.970 m^2 occurred on February 3rd, 2017 due to depressurization of the oil reservoir of GMP – the node connected to the pipeline. The most dangerous emergency situation for the environment occurred on 19 November, 2021 during the depressurization of the pipeline belonging to the underground networks of PTUO OGPD "Okhtyrkanaftogaz" PJSC "Ukrnafta" and caused soil contamination by petroleum products with excess of the maximum allowable concentration – more than 851 times, by chlorides – 700.1 times more.

In order to prevent emergencies, it is necessary to make the possible causes of technical risk and the risk of failure more systematic. Factors of the technical condition of the investigated section of the pipeline according to the pipe inspections determine the impact on the probability of an accident, the parameters of defects detected by in-pipe projectiles (table 2). The high accuracy of measurement of geometrical parameters of defects by in-tube shells with high resolution allows carrying out calculations of defective sites based on durability. According to the calculation on durability, dangerous defects are defined in those zones where a pipeline destruction may occur. Dangerous defects must be repaired as soon as possible. Some of the defects, which remain in the pipes at the moment of investigation, for example, during in-pipe diagnostics, do not require urgent actions concerning repairs, but these defects can further develop and become dangerous. Structural and technological factors determine the impact on the probability of an accident of the design features of pipeline networks and the quality of construction and repair work. Factors of operational load of potentially dangerous pipelines define the impact on the probability of an accident based on the degree of loading of the construction during operation and take into account the cyclical load of internal or external transport pressure, the placement of compressor stations in the study area, and the possibility of water hammer. Factors of corrosion influence determine the influence on the probability of an accident of pipeline system parameters that contribute to the occurrence and development of corrosion defects. Anthropogenic factors determine the probability of damage to pipeline networks due to anthropogenic activity in the area of their location, which is to increase the risk of damage to the pipeline because of unauthorized work on their routes and accidents at neighboring sites. Factors of natural influences are the parameters that characterize the possibility of damage to the pipeline due to soil movement. These factors are determined by the landscape-geochemical position, climatic and hydrogeological conditions of the territory of the control objects, namely, oil and gas pipelines.

According to the monitoring of the methodology of risk analysis during the operation of hazardous industrial facilities, it should be mentioned that the problem of taking into account the non-stationarity of technological processes to solve the problems of managing risk minimization in the oil and gas complex has never been considered before. The applied technologies of monitoring risk management during the operation do not take into consideration the constantly changing non-stationary nature of production processes and their systemic interconnections.

At the first stage of the risk analysis, according to the models of "fault trees" for the events known as "Depressurization of process equipment" and "Explosion in the heating module", there are factors which cause non-stationarity of technological processes due to both external and internal reasons for the operation of technological equipment.

The second stage of the "fault tree" model is the failure of elements of technological equipment in the form of depressurization with the release of the product from the apparatus, which leads to spillage, evaporation, fire transformation according to scenarios that are considered using the subsequent construction of models of "event trees".

The main reasons for the technical risk of pipeline failures in accordance with Table 3 [10].

In order to build a "fault tree" of technological installations, taking into account non-stationarity, the following sequence is recommended in terms of algorithmization [11]:

− quantitative assessment of non-stationary indicators belonging to HIF;

− construction of correlation matrices of the impact of damaging factors on the degree of synergistic risk;

− correlation analysis of the frequency of emergency situations on the value of coherence and correlation interval of emergency events;

− building models of "fault trees".

Table 2 – Factors for assessing the feasibility of accidents in oil and gas transport pipelines

Name of the group of factors	Names of factors
Factors of the technical condition of the oil and gas pipeline section according to non-destructive testing	1. The number of dangerous defects. 2. The relative indicator of loss of communication strength due to the presence of dangerous defects. 3. The amount of time needed for repairs of sites with dangerous defects. 4. The number of detected minor defects. 5. The probability of developing minor defects before reaching a dangerous state.
Structural and technological factors	1. The length of the communication section. 2. Structural and dimensional parameters of communication. 3. The thickness of the communication walls. 4. Steel grade, and its mechanical characteristics. 5. The service life of the area. 6. The manufacturer of communications. 7. The category of the site according to the complexity of the works. 8. Availability of protective coatings. 9. Characteristics of underwater transitions.
Factors of operational loads of pipelines	1. Passport productivity. 2. Average annual volumes of loading. 3. Data on pressure. 4. Bearing capacity of the soil. 5. Physical-chemical characteristics of the transportation product.
Factors that cause corrosion	1. Soil corrosion activity. 2. The climatic region. 3. The type of external insulating coating (material, design and the method of application). 4. The duration of operation of communication without any replacement of an insulating covering. 5. The protection of a site along the length by means of electro-chemical protection. 6. Data on the presence of areas where communication comes from the ground into the water or air and vice versa. 7. The corrosion activity of the transported product.
Anthropogenic factors	1. The level of economic activity near the site of the underground communication. 2. The location of neighboring industrial facilities (gas pipelines, product pipelines, roads, etc.).
Natural factors	1. The possibility of soil deformation (landslides, land subsidence, soil lifts etc.). 2. The possibility of uneven land subsidence. 3. The possibility of soil erosion due to changes in riverbeds or groundwater. 4. The terrain change.

Table 3 – The main reasons for the technical risk of pipeline failures

Groups of reasons	Reasons
Industrial (man-made)	– internal corrosion of pipes; – defects of construction origin: dents, scratches; – defects which are of metallurgical origin: metal shrinkage, bubbles, axial pores, fine-grained cracks, cuts; – weld defects: overlap, craters, cracks, incomplete fusion, incomplete penetration.
Natural	– landslides and land subsidence; – abundant precipitation.
Anthropogenic	– errors in the design, construction, and maintenance, errors the operation of pipelines; – excavation work; – malicious damage.

Requirements for the construction of formalized models of “event trees” taking into account the non-stationarity of risks:

− data collection and statistical analysis of occurred emergencies;

− accounting and analysis of non-stationarity of explosion and fire hazard and toxicity of combustible substances;

− analysis of the conditions for the sequence of scenarios which are about the development of an emergency event;

− assessment of the frequency of implementation of the conditions for the development of emergencies;

− determination of the structure of the “event trees” based on the calculation of probabilistic estimates according to the accident development scenarios;

− the definition of regulations for technical and organizational solutions to localization and liquidation of emergencies.

− assessment of the frequency of implementation of the conditions for the development of emergencies;

− determination of the structure of the “event trees” based on the calculation of probabilistic estimates according to the accident development scenarios;

− the definition of regulations for technical and organizational solutions to localization and liquidation of emergencies.

The impact assessment of emergencies is specifically determined in the same way as for accident-free ones. Taking into account the duration of the accident, the dynamics of impact reduction is determined and, in case of cumulative impact, average values can be determined. The assessment is based on the determination of the complex impact and its significance, the development of proposals for the strategy for the elimination of the accident.

It is difficult to quantify the environmental change for most environmental impact assessments. The proposed methodology is a semi-quantitative one, the score-based assessment is given below. The significance of anthropogenic disturbances of the natural environment at all levels is assessed according to the following parameters: spatial scale; time scale; and intensity. For a comprehensive assessment of the impact on the natural environment, a multiplicative (multiplication) calculation methodology is used, in contrast to the additive (addition) methodology adopted for the social sphere.

Determination of the spatial scale of impacts is carried out on the basis of the analysis of technical solutions, mathematical modeling, or on the basis of expert assessments.

Comprehensive (integral) assessment of the impact on individual components of the natural environment from various sources of impact

A comprehensive assessment is a multistep process.

Stage 1. To determine the complex impact on individual components of the natural environment, it is necessary to use tables with impact criteria.

The complex score is determined by the formula

$$Q_{integr}^{i} = Q_i^t \cdot Q_i^s \cdot Q_i^j, \qquad (1)$$

where Q_{integr}^{i} – is a complex evaluation score for a given impact; Q_i^t – the score of temporary impact on the i’s component of the natural environment; Q_i^s – the score of spatial impact on the i’s component of the natural environment; Q_i^j – the score of intensity impact on the i’s component of the natural environment.

In case of the oil spill, we have the following data:

$$Q_{integr}^{i} = Q_i^t \cdot Q_i^s \cdot Q_i^j = 2 \cdot 1 \cdot 3 = 6 .$$

Therefore, due to the impact of low significance, the effects are detected, but the magnitude of the impact is quite low (with or without mitigation and also within acceptable standards), or the receptors are of low sensitivity/value.

The impact of the average duration– the impact that occurs over a period of time covering from one season (3 months) to 1 year.

The local impact is the impact that affects the components of the natural environment, limited by the territory (the water area) of the exact location of the object or slightly exceeding the area (up to 1 km^2).

The moderate impact is based on the changes in the natural environment that exceed the limits of natural variability, lead to a violation of individual components of the natural environment. The natural environment retains the ability to self-healing.

Stage 2. The category of significance is determined by the range of values depending on the score obtained due to the calculation of the comprehensive assessment. With an integral score of 6 points, the significance category is defined as an impact of low significance. The risk matrix is built on the basis of data on consequence/ severity, strength of knowledge and probability (Table 4).

High severity of consequences that means death, serious personal injury or illness, extensive pollution, extensive damage to equipment or material assets, significant deferred production, substantial gas/oil leak, safety integrity weakened for all or large parts of the facility. For the period of last five years probability of the emergences with oil spills is high, i.e. probable, occurrence assessed as possible several times in a year. Strength of knowledge is strong.

An overall risk assessment obtained by comparing consequences, probability and strength of knowledge.

Table 4 – Enhanced risk matrix [12]

		Probability		
Consequence/ severity	**Strength of knowledge**	**Low**	**Medium**	**High**
Low	**Weak**	Medium	Medium	High
	Medium	Low	Medium	High
	Strong	Low	Low	Medium
Medium	**Weak**	Medium	High	High
	Medium	Medium	High	High
	Strong	Low	Medium	High
High	**Weak**	High	High	High
	Medium	High	High	High
	Strong	Medium	High	High

Discussion

In order to comply with the requirements of environmental safety for each field, a plan for localization and elimination of emergencies (PLES) is developed, according to which potentially dangerous objects are identified in terms of accidents. In particular, production wells and injection wells are among of them. The plan contains instructions for notifying the relevant services and organizations that should be involved in the elimination of accidents and their consequences, a list of necessary technical means, neutralizing reagents, and methods of collection and disposal of pollutants. The hazard analysis of the entire system of production, collection and transportation of hydrocarbon products shows that the most probable accidents during oil and gas production are oil and gas (open) fountains with subsequent fire and oil and gas pipeline bursts and the ignition of emissions.

The most probable occurrence of an accident related to the collection and transportation in the field is the spillage of oil and water in the event of a pipeline leak due to corrosion or mechanical damage.

To prevent the causes of accidents and mishaps, oil and gas operators must:

1. Strictly adhere to the technological mode of operation.

2. Timely eliminate oil and gas leaks in flange connections and stuffing boxes.

In case of a spill of oil and oil products, the soil is cut to the depth of contamination (approximately 0.15 m). The polluted area must be outlined with 20-25 cm depth of plowing. In case of average and considerable spills in the field, it is necessary to build trenches and equip them with protective screens for the prevention of intensive infiltration of oil products into soil. Spill collection must be carried out using special oil collection equipment. An adsorbent (such as hydrophobized perlite, vermiculite) is applied to the surface of contaminated areas before applying the fertile layer of soil at the rate of 0.1…0.2 kg per 1 m^2 of contaminated area. As soon as the pollutants are collected from the soil surface, technical and biological reclamation of the territory is carried out, which is regulated by the relevant regulatory documents.

The frequency of bursts of pipelines increases due to their exploitation, the untimely replacement of worn pipes, and insufficient inhibitory protection. Defectoscopy of pipe products before the installation of pipelines and the use of inhibitory corrosion protection of pipes during their operation are deterrents against the impact of man-made causes. Anthropogenic causes are prevented by timely maintenance of pipelines (the planned replacement of worn-out pipes, carrying out the necessary earthworks in the area of pipeline networks with the help of an operator who is familiar with the exact location of the routes) [13].

The scheme of distribution of management goals and strategies according to [14] is shown in Table 5.

Since an environmental risk is a combination of the probability or frequency of occurrence of a certain hazard and the magnitude of the consequences of such an event, therefore, recommendations for reducing risks of an accident should be based on: the reduction in the probability of accidents; and the minimization of the consequences.

In addition, the proposed activities should be both technological and organizational in nature.

Technological measures are as follows:

– the restriction on the use of hazardous technologies;

− the reduction in the number of explosive and toxic substances which are used;

− the creation of systems for automatic control and provision of design parameters (pressure, temperature, volume);

− the creation of safety zones (explosion protection, separating distances);

− the location of technological equipment, taking into account the organization of emergency evacuation routes for personnel from production facilities and recommendations given by the rescue team.

Organizational measures are as follows:

− the development of safety regulations and their observance;

− fire protection and emergency signaling;

− the manual for the personnel training;

− the allocation of responsibilities for the enterprise safety;

− the organization of control of storage sites for toxic and explosive substances, as well as waste storage sites, etc.

Table 5 – The scheme of distribution of management goals and strategies [14]

Security conditions of the object of management	Objectives of security management
Normal security status. Optimal values of the security parameter	Optimal security management
Normal security status. Values of the safety parameter that correspond to the normal one	Security management
	Transition to optimal security management
Normal security status. Negative trend. Threat	Elimination of threats
	Prevention of forecasted emergency
	Prevention of predicted violations of the normal state of security
Violation of the normal state of security	Transition from infraction to normal security
Violation of the normal state of security. Emergency situation	The achievement of an acceptable level of security
	Transition from emergency to normal security
Violation of the normal state of security. Emergency response	Minimization of the consequences of an emergency
	Transition to normal security

Conclusion

With regard to various conditions and levels of damage, there are certain proposals given for practical implementation to ensure the safety of wells and pipelines in the process of monitoring, research, and the development of a reconstruction project and its examination. The current regulatory documents and international standards governing the process of risk assessment in the event of an emergency at oil production facilities became the methodological basis of the studies. The scientific and methodological basis of research is a modified deterministic and probabilistic approach to determining the risk of an emergency using fuzzy logic methods in the form of neural networks. To test the developed methodology, data on accidental oil spills in the Sumy region for the period of 2017–2021 were analyzed. As a result of the research, it was established that the significance of anthropogenic disturbances of the natural environment at all levels is assessed by the following parameters: spatial scale; time scale; intensity. In the event of an oil spill incident, the study statistics gave a comprehensive impact score of 6, indicating an impact of low significance, impacts are being experienced, but the magnitude of the impact is quite low (with or without mitigation) and within acceptable standards or receptors have low sensitivity. In the cases of individual assessments in determining environmental risk, then the following results were obtained: time parameter – impact of medium duration, spatial parameter – local impact, intensity – moderate impact.

REFERENCES

1. Azarov, S., Sydorenko, V., & Zadunay, A. (2019). Rozrobka zasad klasyfikacii' nebezpechnyh krytychno vazhlyvyh ob’jektiv iz zagrozoju vynyknennja tehnogennyh nadzvychajnyh sytuacij [Development of basics of hazardous and critically important objects classification considering the threat of an anthropogenic emergencies]. *Technogenic and ecological safety*, 6(2/2019), 3–11. DOI: 10.5281/zenodo.3558940. [in Ukrainian].

2. Poberezhny, L., Yavorsky, A., Tsyh, V., Stanetsky, A., & Grytsanchuk, A. (2017). Pidvyshhennja rivnja ekologichnoi' bezpeky truboprovidnyh merezh naftogazovogo kompleksu Ukrai'ny [Improving the environmental safety of pipeline networks of oil and gas complex of Ukraine]. *Technogenic and ecological safety*, 1, 24–31. [in Ukrainian].

3. Xiao, J., Wang, Y., Shi, P., Yang, L., Chen, L.-D. (2014). Potential effects of large linear pipeline construction on soil and vegetation in ecologically fragile regions. *Environmental Monitoring and Assessment*, 186(11), 8037–8048. DOI: 10.1007/s10661-014-3986-0.

4. Sun, T. Y., Bornhöft, N. A., Hungerbühler, K., & Nowack, B. (2016). *Dynamic probabilistic modeling of environmental emissions of engineered nanomaterials*. *Environmental Science & Technology*, 50(9), 4701–4711. DOI: 10.1021/acs.est.5b05828.

5. Laine, V., Goerlandt, F., Baldauf, M., Mehdi, R. A., Beşikçi, E. B., Koldenhof, Y., Al-Quhali, M. A., & Backer, H. (2018). *OpenRisk guideline for regional risk management to improve european pollution preparedness and response at sea*. OpenRisk HELCOM – Helsinki Commission, 108.

6. John, A., Nwaoha, T. C., & Kpangbala, T. M. (2017). A collaborative modelling of ship and port interface operations under uncertainty. *Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment*, 231(1), 165–176. DOI: 10.1177/1475090216629704.

7. John, A., Yang, Z., Riahi, R., & Wang, J. (2016). A risk assessment approach to improve the resilience of a seaport system using Bayesian networks. *Ocean Engineering*, 111, 136–147. DOI: 10.1016/j.oceaneng.2015.10.048.

8. Lavasani, S. M., Zendegani, A., & Celik, M. (2015). An extension to Fuzzy Fault Tree Analysis (FFTA) application in petrochemical process industry. *Process Safety and Environmental Protection*, 93, 75–88. DOI: 10.1016/j.psep.2014.05.001.

9. Tao, Z., Liu, X., Chen, H., Chen, Z. (2015). Group decision making with fuzzy linguistic preference relations via cooperative games method. Computers & Industrial Engineering, 83, 184–192. DOI: 10.1016/j.cie.2015.02.016.

10. Govdyak, R. M. (2008). *Pidvyshhennja efektyvnosti magistral’nyh gazoprovodiv na piznij stadii’ ekspluatacii’* [*The increase of the efficiency of the main gas- pipelines on the late stage of exploitation*]: dissertation … doctor of technical sciences: 05.15.13. Ivano-Frankivs'k. [in Ukrainian].

11. Shi, L., Shuai, J., & Xu, K. (2014). Fuzzy fault tree assessment based on improved AHP for fire and explosion accidents for steel oil storage tanks. *Journal of hazardous materials*, 278, 529–538. DOI: 10.1016/j.jhazmat.2014.06.034.

12. Norwegian Oil and Gas. (2017). *Norwegian Oil and Gas recommended guidelines on a common model for Safe Job analysis* (*SJA*).

13. TOV “NC “Ekologija” (2019). *Zvit z ocinky vplyvu na dovkillja planovanoi’ dijal’nosti z vydobuvannja korysnyh kopalyn NGVU “Dolynanaftogaz” PAT “Ukrnafta” na Ripnjans’komu rodovyshhi* [*Environmental Impact Assessment Report of the planned mining activity of NGVU "Dolynanaftogaz" PJSC "Ukrnafta" at the Ripnyansky field*]. Odesa: TOV “NC “Ekologija”. [in Ukrainian].

14. Bandurian, B., Kovalevskyj. V., & Tsvaigov, D. (2021). Kryterii’ ocinky stanu bezpeky [Criteria of safety condition assessment]. *Technogenic and ecological safety*, 10(2/2021), 10–16. DOI: 10.52363/2522-1892.2021.2.2. [in Ukrainian].

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НАУКОВО-МЕТОДИЧНІ ПІДХОДИ ДО ОЦІНКИ БЕЗПЕКИ КОМПЛЕКСІВ НАФТОВИДОБУВАННЯ ЯК ПОТЕНЦІЙНО НЕБЕЗПЕЧНИХ ОБ'ЄКТІВ

Мета статті полягає у визначенні оптимального підходу до проведення оцінювання ризику об’єктів нафтового видобування як потенційно небезпечних об’єктів. Методологічною основою для проведених досліджень стали чинні нормативні документи та міжнародні стандарти, що регулюють процес оцінки ризику у разі виникнення надзвичайної ситуації на нафтовидобувних об’єктах. Науково-методичною базою досліджень є модифікований детермінований та ймовірнісний підходи до визначення ризику виникнення аварійної ситуації з використанням методів нечіткої логіки у вигляді нейронних мереж. Значимість антропогенних порушень природного середовища всіх рівнях оцінювалася за такими параметрам: просторовий масштаб; часовий масштаб; інтенсивність. Зіставлення значень ступеня впливу по кожному параметру оцінювалося за бальною системою за розробленими критеріями. Комплексна (інтегральна) оцінка навантаження на окремі компоненти природного середовища від різних джерел впливів була встановлена на рівні 6 балів, що ідентифікується як вплив низької значимості. Дослідження проводилися на прикладі аварійних ситуацій на території Сумської області за період 2017–2021 рр. Встановлено, екологічний ризик є комбінацією ймовірності або частоти виникнення певної небезпеки та величини наслідків такої події, тому рекомендації щодо зменшення ризиків від аварії повинні зводитися до зниження ймовірності аварій та мінімізації наслідків. У статті надані рекомендації організаційного та технологічного характеру щодо усунення або зниження ступеня ризику від аварійних ситуацій, пов’язаних з розливом нафти.

Ключові слова: екологічна безпека, ризик, оцінювання небезпеки, ймовірнісний підхід, детермінований підхід, нечітка логіка, видобуток нафти, аварії.

ЛІТЕРАТУРА

1. Азаров С. І., Сидоренко В. Л., Задунай О. С. Розробка засад класифікації небезпечних критично важливих об'єктів із загрозою виникнення техногенних надзвичайних ситуацій. *Науково-технічний журнал «Техногенно-екологічна безпека»*. 2019. Вип. 6(2/2019). С. 3–11. DOI: 10.5281/zenodo.3558940.

2. Підвищення рівня екологічної безпеки трубопровідних мереж нафтогазового комплексу України / Побережний Л. Я. та ін. *Науково-технічний журнал «Техногенно-екологічна безпека»*. 2017. Вип. 1. С. 24–31.

3. Potential effects of large linear pipeline construction on soil and vegetation in ecologically fragile regions / Xiao J. et al. *Environmental Monitoring and Assessment*. 2014. Vol. 186(11). P. 8037–8048. DOI: 10.1007/s10661-014-3986-0.

4. Dynamic probabilistic modeling of environmental emissions of engineered nanomaterials / Sun T. Y. et al. *Environmental Science & Technology*. 2016. Vol. 50(9). P. 4701–4711. DOI: 10.1021/acs.est.5b05828.

5. OpenRisk Guideline for Regional Risk Management to Improve European Pollution Preparedness and Response at Sea / Laine V. et al. OpenRisk HELCOM - Helsinki Commission, 2018. 108 p.

6. John A., Nwaoha T. C., Kpangbala T. M. A collaborative modelling of ship and port interface operations under uncertainty. *Proceedings of the Institution of Mechanical Engineers, Part M: Journal of Engineering for the Maritime Environment*. 2017. Vol. 231(1). P. 165–176. DOI: 10.1177/1475090216629704.

7. A risk assessment approach to improve the resilience of a seaport system using Bayesian networks / John A. et al. *Ocean Engineering*. 2016. Vol. 111. P. 136–147. DOI: 10.1016/j.oceaneng.2015.10.048.

8. Lavasani S. M., Zendegani A., Celik M. An extension to Fuzzy Fault Tree Analysis (FFTA) application in petrochemical process industry. *Process Safety and Environmental Protection*. 2015. Vol. 93. P. 75–88. DOI: 10.1016/j.psep.2014.05.001.

9. Group decision making with fuzzy linguistic preference relations via cooperative games method / Tao Z. et al. *Computers & Industrial Engineering*. 2015. Vol. 83. P. 184–192. DOI: 10.1016/j.cie.2015.02.016.

10. Говдяк Р. М. Підвищення ефективності магістральних газопроводів на пізній стадії експлуатації : дис. … д-ра техн. наук: 05.15.13. Івано-Франківськ. 2008.

11. Shi L., Shuai J., Xu K. Fuzzy fault tree assessment based on improved AHP for fire and explosion accidents for steel oil storage tanks. *Journal of hazardous materials*. 2014. Vol. 278. P. 529–538. DOI: 10.1016/j.jhazmat.2014.06.034.

12. Norwegian Oil and Gas recommended guidelines on a common model for Safe Job analysis (SJA). Norwegian Oil and Gas, 2017. 21 p.

13. Звіт з оцінки впливу на довкілля планованої діяльності з видобування корисних копалин НГВУ «Долинанафтогаз» ПАТ «Укрнафта» на Ріпнянському родовищі. Одеса: ТОВ «НЦ «Екологія», 2019. 168 с.

14. Бандурян Б. Б., Ковалевський В. В., Цвайгов Д. Л. Критерії оцінки стану безпеки. *Науково-технічний журнал «Техногенно-екологічна безпека»*. 2021. Вип. 10(2/2021). С. 10–16. DOI: 10.52363/2522-1892.2021.2.2.