TECHNOLOGICAL AND MANAGEMENT SOLUTIONS TO PREVENT EMERGENCIES AT OIL AND GAS FACILITIES

Teodoziïa **YATSYSHYN**[1], Lesya **SHKITSA**[2]**,** Mikhaylo **LYAKH**[3]**,** Vasyl-Danylo **LIAKH**[4]

[1] Ivano-Frankivsk National Technical University of Oil and Gas, Department of Environmental Protection Technology, Ivano-Frankivsk, Ukraine, [2]Ivano-Frankivsk National Technical University of Oil and Gas, Engineering and Computer Graphics Department, Ivano-Frankivsk, Ukraine, [3] Ivano-Frankivsk National Technical University of Oil and Gas, Oil and Gas Equipment Department, Ivano-Frankivsk, Ukraine, [4] Technical University of Kosice, Faculty of Manufacturing Technologies, Presov, Slovac Republic

teodoziia.yatsyshyn@nung.edu.ua

Keywords: emergency, oil and gas, environment, defectoscopy

Abstract*: Oil and gas production is accompanied by technological processes that can pose a significant threat to the environment. The analysis of conditions of occurrence of ecologically dangerous emergency situations in oil and gas production branch is presented. This became the basis for the formation of a technical solution to increase the environmental safety of hydrocarbon production processes. The system of diagnostics of the equipment for rejection of rods is improved. The main purpose of improving the rod magnetic flaw detector was to reduce emergencies with the rods of deep pumping units by rejecting the rods with defects. The improvement of the rod magnetic flaw detector was to reduce the scattering of the magnetic field in order to improve the quality of flaw detection. The use of this device will prevent accidents, which are accompanied by energy and resource costs, as well as causing environmental pollution by fluids. Based on the above research results the management model of environmental safety of oil and gas well is suggested.*

1. INTRODUCTION

The increase in the volume of global oil and gas production is accompanied by both the introduction of modern methods of intensification of depleted fields and the search for the latest high-beta deposits. At the same time the number of drilled wells carrying potential ecological risk to the environment is growing. These facilities pose a threat to the environment both during regulated technological processes and during emergencies.

Emergency mode during construction, operation and overhaul of a well may arise due to various factors, the following complex technogenic accidents - open oil and gas fountains. They are extremely dangerous for the surrounding areas and settlements, whith corresponding effects the economic costs.

Most often the following scheme works at enterprises: an emergency situation → economic damage calculation → determination of social damage (if a claim is made) → determination of environmental damage (if a claim is made). Unreasonable data regarding the probabilities of emergencies and consequences (economic, social and environmental) or a one-sided assessment of the occurrence of an undesirable event without systematic identification of all possible consequences is the main problem in determining risks.

Trends of modern environmental policy of oil and gas complex of Ukraine demonstrate the desire of oil and gas companies to improve the environmental management system to meet the requirements of the EU and strengthen the sustainable position in the European market. Such transformations of environmental safety management are reflected in the environmental modernization of modern production, as well as improvement of the relationship of the institutional system of society with the environment.

2. ANALYSIS OF THE CURRENT STATE OF THE EMERGENCY PREVENTION SYSTEM AND TECHNOLOGICAL SOLUTIONS OF EQUIPMENT AT OIL AND GAS FACILITIES

In the conditions of modern development of production there is a need to overcome or at least partially minimize the identified contradictions between the level of technological process and the means that support the environmental safety of human life and protect his health from the negative effects of industry [1]. In the work [2] it is observed that environmental management becomes preventive in nature, that is, to prevent the emerging of environmentally hazardaos substances of production processes, rather than the elimination of already produced pollution by using high-cost cleaning systems.

Despite the constant improvement of equipment, means and systems of emergency diagnostics and protection during the life cycle of oil and gas wells, there is a possibility of uncontrollable or poorly controlled phenomena and processes, classified as an accident and posing a particular danger to the biosphere and, above all, to the population [3]. The practice of foreign oil and gas companies shows the need to develop predictive systems to be able to respond quickly and clearly in case of emergency situations and special attention to preventive measures. The complex technogenic impact on the components of the natural environment can often have irreversible negative consequences. The experience of the last 10 years shows that economic, environmental and social problems cannot be solved in isolation from each other. The anticipation and prevention of problems by planning and forecasting is more economically advantageous compared to the costs of eliminating their consequences [4].

Lifecycle management system as one of the significant elements of environmental management systems is aimed at minimizing environmental and socio-economic problems associated with a product or product range during its life cycle and value chain. The lifecycle management system allows you to quickly track the life cycle and balance of the product and carry out continuous improvement of the productive system [5]. In the scientific work of Stremberg L.M. it is noted that life cycle assessment (LCA) is a systematic approach to determine the environmental safety of the object and a tool for the initial stage of environmental impact assessment [6]. DSTU ISO 14040:2013 [7] states that LCA usually does not cover economic or social aspects of products, but the approach and life cycle methodology described in DSTU ISO 14040:2013 can be applied to these aspects as well. The use of eco-efficiency methodology in LCA is noted in the work of A. C. Kokossis, F. Thompson, and T. K. Das [8].

Given the above facts, attention is paid to the diagnostic systems of deep pump rods and existing defectoscopy system designs. The rods work in difficult conditions due to high temperature, aggressive environment, high dynamic and cyclic loads. The failure of rods in the well is a difficult economically costly emergency situation. The rod magnetic flaw detector is known [9], containing a frame with a magnetic flaw detector system. The magnetic system of this flaw detector is quite complicated and low-tech in manufacturing and the possibility of its operation in industrial conditions directly on the oil producing well.

The known magnetic flaw detector [10], containing a frame, a magnetizing articulated system attached to it in the form of a П-shaped magnetic wire with permanent magnets. There is also a magnetic field sensor, connected with electronic recording equipment. The main disadvantages of this magnetic flaw detector are that: the flaw detector of this design cannot be used on the well in the process of running the rods (in the vertical position); the limitation of diameters, controlled from 30 mm to 130 mm, and the diameter of the rods from 13 mm to 28 mm, which cannot be controlled by this flaw detector; this flaw detector controls only the inner surface of pipes, and rods are solid round shapes.

The known flaw detector [11] contains a frame with a magnetizing system installed on it, made in the form of a П-shaped magnetic wire with permanent magnets connected to the ends of the magnetic wire hinged. There is a magnetic field sensor connected to the electronic recording equipment. The disadvantage of the known magnetic flaw detector is that it cannot operate in the vertical position when lowering the rods into the well. Also the connection of the ends of the magnetic wire and the permanent magnet hinged contributes to the dissipation of the magnetic field, which reduces the quality indicators of the whole magnetic flaw detector.

Analysis of the current state of the system of prevention of dangerous situations at the objects of the oil and gas complex shows the need to improve the current system, which would avoid the identified shortcomings.

3. ENVIRONMENTAL MANAGEMENT OF THE LIFE CYCLE OF OIL AND GAS WELLS

Given the current situation in the oil and gas industry, there is a need to develop environmental management of a preventive nature, where the priority aspect is the focus on the prevention of dangerous processes for the environment during production processes. Management approaches based on the elimination of harmful effects, which have already happened; need to be reformed in prevention. Such transformations of management of ecological safety should be realized by modernization of modern production with the use of eco-efficient technologies and approaches, as well as improvement of interrelations of institutional system of society with the environment [12, 13]. The environmental management system is a tool for the development and implementation of environmental policy and environmental management aspects in order to ensure the environmental safety of the population and the environment.

The condition of the environment within the location of oil and gas production facilities is subjected to intensive technogenic impacts. "Oil and gas production object (oil and gas well) - the natural environment" is a complex multifactor system with diverse internal and external relations. The study of the system "oil and gas well - the environment" should be carried out taking into account the method of structural division into separate time intervals - stages of the life cycle. Each stage should be studied from the position of environmental safety and identify objects and processes that require improvement to improve the environmental performance of production. It is important to assess and predict environmental hazards in production to prevent their occurrence, which is more economically beneficial. In the environmental risk management system, it is necessary to identify the cause-and-effect relations of the occurrence of environmentally hazardous situations. For this purpose, the method of Ishikawa diagram construction was applied, which allows visualizing the actions of possible factors and identifying the most influential causes leading to an undesirable outcome. The diagram identifies the factors that can be managed. Thus, a diagram of the factors influencing the occurrence of environmentally hazardous situations at oil and gas production facilities was built (*fig. 1*).

On the basis of the constructed scheme, it is possible to trace the factors and their influence in the formation of ecologically dangerous situations in oil and gas production. These factors are determined on the basis of the analysis of the causes of formation of hydrocarbon production wells in different conditions and at different stages of the life cycle according to the materials of Kuzmenko V.A. [14]. 100 wells were chosen for the research. Often a combination of several factors at one well was observed, among which the organizational factor should be noted. Human error can occur both in the design and manufacturing phases of drilling equipment, that is, before work begins on the rig site and in decision-making at the time of an emergency.

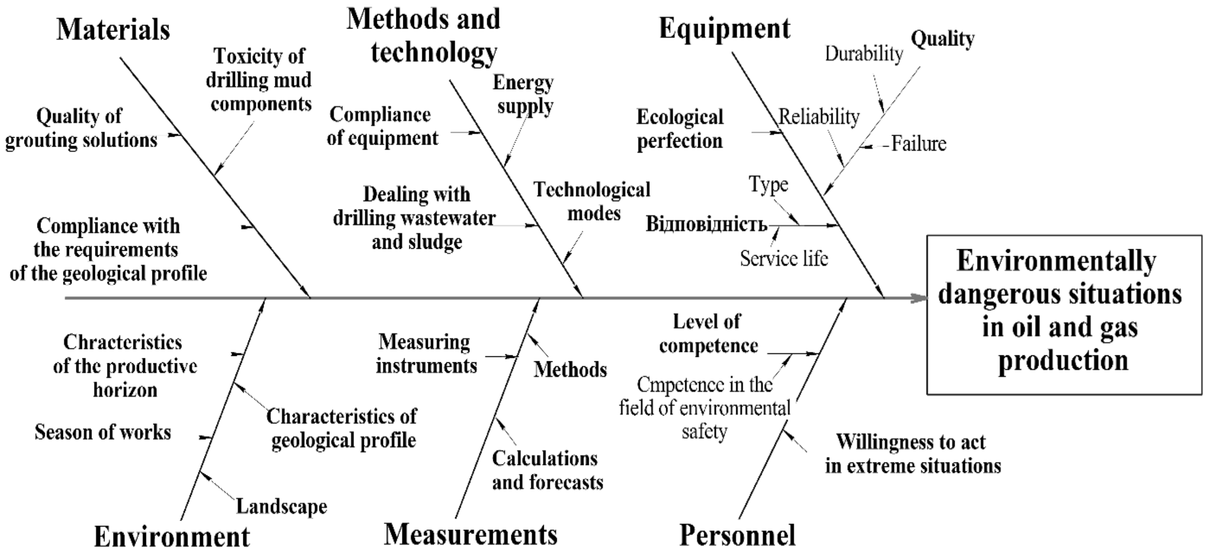


Fig 1. Scheme of factors influencing the occurrence of environmentally hazardous situations at oil and gas production facilities

The main number of open fountains is observed at gas fields. This is explained by peculiarities of construction of gas wells and probable underestimation of dangers that may accompany this process. There is also an adaptation of oil field fracturing technology and techniques to gas fields. Fountains can be caused by opening of lower productive horizons without overlapping the upper ones, especially with abnormally high formation pressure. Also, a high frequency of occurrence of accidental fountains occurs during exploratory drilling.

When examining the accident sites, sources of information did not indicate such factors as obsolete equipment, untimely replacement of equipment that has expired, lack of preventive repair work [15]. However, for the specifics of the oil and gas production industry of Ukraine, the wear and tear of equipment is an extremely acute problem. It is important to note the fact that the equipment, used its working life, is present not only at the stages of well construction, but also on the wells, taken out of operation (abandoned wells), which often remain without control of the responsible organizations [16]. This state of affairs forms a high risk of emergencies, including gas oil and water manifestations and open fountains. Thus, the environmental safety of oil and gas facilities can be assessed in terms of the impact of these facilities on the environment and in terms of the equipment of production with modern environmentally safe technologies and equipment.

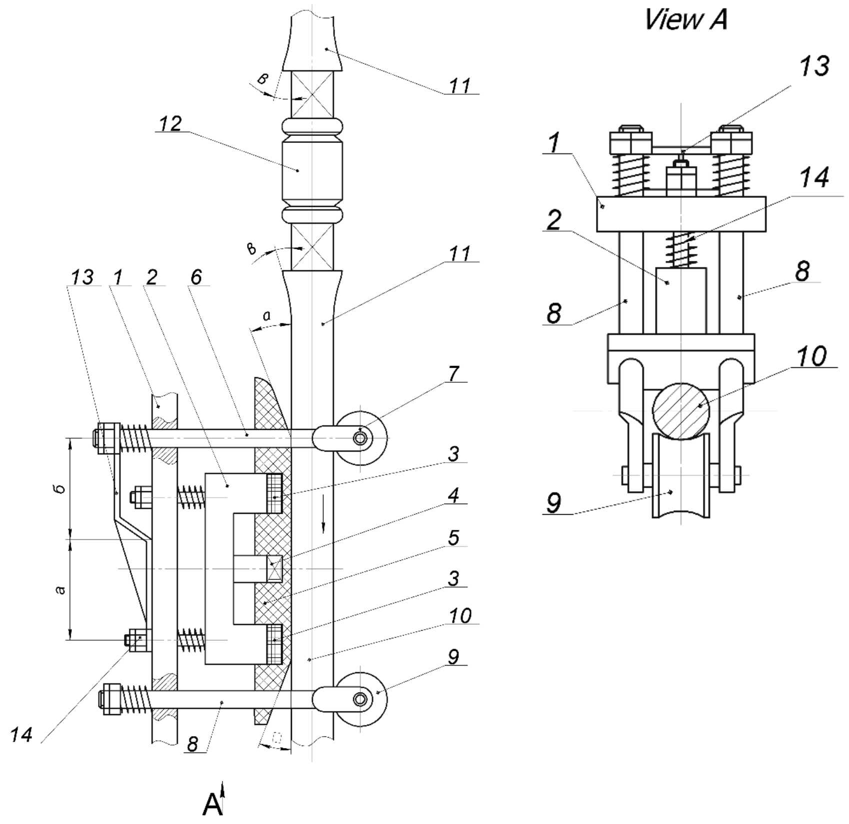
4 SYSTEM OF DIAGNOSTICS OF DEPTH PUMP RODS DEFECTS

The rods are the main element through which the drive - the forward movement of the downhole plunger pump in the process of oil production is carried out. As noted, rods work in difficult conditions, also wells may not be strictly vertical, but curved, which creates additional unfavorable conditions for sucker rod operation. All this will accelerate rod failure if there are even minor defects in them. It takes a lot of time and high-cost equipment to eliminate boom-related accidents. Defects on rods may appear during transportation, storage and handling. Therefore, it is advisable to inspect the rods directly during lowering into the well and remove the rods with defects, which will quantitatively reduce the occurrence of extreme (emergency) situations related to the rods.

The main purpose of development of this device was to reduce the emergency situations with the rods of deep-well pumping units by preventing the launch into the well of the rods with defects. Improvement of the rod magnetic flaw detector was made by reducing the dispersion of the magnetic field in order to improve the quality indicators of flaw detection. Permanent magnets are rigidly connected to the ends of the Π-shaped magnet wire without additional magnetic cores. For protection against mechanical damage a protective element made of non-magnetic material is installed on the ends of the magnetic wire with permanent magnets and on the sensor. The Π-shaped magnetic core is connected to the frame of the spring-loaded guide rods. To keep the flaw detector in a vertical position when lowering the rods into the borehole, spring-loaded rods with rollers are installed in the holes on the frame and the protective element. The profile of the protective element surface ends made of non-magnetic material, contacting with the rod, is made at an angle corresponding to the dropout at the ends of the rods to ensure the possibility of the magnetic flaw detector transition through the dropout at the ends of the rods and the coupling. To ensure parallel lifting to the boom axis of the Π-shaped magnetic core with the protective element when passing the blasted ends of the rod, there is a lever balancing mechanism on the frame, contacting with two roller guide rods at one end. It, in turn, contacts the surface profile of the rods. The other end of the lever balancing mechanism contacts the lower guide of the spring-loaded Π-shaped magnet wire.

Fig.2.a shows a general view of the rod magnetic flaw detector in operating condition on the smooth part of the boom. A bottom view of the flaw detector on the boom in the working condition is shown in *fig. 2.b*. The rod magnetic detector consists of a frame 1 with a magnetizing system mounted on it. The magnetic system is made in the form of Π-shaped magnetic wire 2 with permanent magnets 3 and magnetic field sensor 4, located between the permanent magnets 3 and connected to the electronic recording equipment. The protective element 5 of a non-magnetic material (e.g. polyurethane) is to protect the permanent magnets 3 and the magnetic field sensor 4. The holes in the frame 1 and the protective element 5 are

equipped with upper spring-loaded pull rods 6 with a roller 7 and lower spring-loaded guide rods 8 with a roller 9. The element 5 with the blown ends 11 at an angle α contacts the controlled surface of the rod 10. Between the blown ends of the rod 11 there is a coupling 12, and on the frame 1 there is a lever balancing mechanism 13, contacting with the upper spring-loaded rods 6 at one end, and with the lower spring-loaded rod guide 14 П-shaped at the other end.



a. *b.*

Fig 2. Rod magnetic flaw detector: a. - working position on the smooth part of the rod; b. - view A, bottom view.

The rod magnetic flaw detector operates as follows. The rod magnetic flaw detector is mounted on the first, boom 11, which is in vertical position as shown in *fig. 2*. It is descended into the borehole. The rods 10 are connected to each other by couplings 12 and create a rod string. The frame 1 with all the flaw detector elements in addition to the electronic recording equipment is held on the vertical rod 10 by spring-loaded tie rods 6 and 8 in accordance with the rollers 7 and 9. The magnetizing system in the form of a П-shaped magnet wire. The rod magnetic detector is installed on the first rod 11 being in vertical position, as shown in *fig. 2* and is lowered into the borehole. The rods 10 are connected with each other by couplings 12 and create a rod string.

The frame 1 with all the flaw detector elements except for the electronic recording equipment is held on the vertical rod 10 by the spring-loaded tie rods 6 and 8 in accordance with the rollers 7 and 9. The magnetizing system in the form of П-shaped magnet wire 2 with permanent magnets 3 and the magnetic field sensor 4 by protective element 5 is pressed to the surface of the rod 10 by means of guiding spring-loaded rods 14. On the smooth surface of the rods 10 the contact of the magnets 3 and the magnetic field sensor 4 is made through the protective element 5. The ends of the contacting surface of the protective element 5 are made at an angle corresponding to the angle β of the dislocated ends 11 of the rods 10. The angles α and β are close in value. *Fig. 2.b* (view A, bottom view) shows the location of the frame 1, the magnetizing system in the form of a П-shaped magnetic core 2, the lower spring-loaded rod 8, the roller 9, the rod 10, the lever balancing mechanism 13 and the lower guide spring-loaded rod 14.

At the approach of the drop-out end 11 of the rod 10 to the defectoscope the roller 7 goes to the drop-out 11, moving the spring-loaded tie rods 6, and the tie rods 6 press the upper end of the lever balancing mechanism 13. Simultaneously with the roller 7 on the landing 1 to the axis of the rod 10 П-shaped magnet wire 2 with permanent magnets 3, magnetic field sensors 4 and protective element 5, the lower end of the lever balancing mechanism 13 moves the lower spring-loaded link 14 П-shaped magnet wire 2.

In addition, to ensure synchronous movement parallel to the axis of the rod 10 of the П-shaped magnet wire 2 with all the elements connected to it. The distance between the pivot axis of the lever balancing mechanism 13 to the axis of the lower underrun rod 14 "a" and to the axis of the upper spring-loaded rods 6 "b" should be equal. Passing the blasted ends 11 of the rods 10 with couplings 12, the rod magnetic flaw detector without stopping continues to perform the necessary functions.

Application of this device will prevent emergencies, which is accompanied by energy and resource costs, as well as leads to environmental pollution by fluids. The proposed design of the rod magnetic flaw detector has been granted a patent for a useful model.

5. CONCLUSIONS

According to the methodology of life cycle assessment, the oil and gas production industry requires significant modernization in the direction of greening both the consciousness of the personnel of different levels, and all the processes and equipment. Using the methodology of life cycle assessment, it is proposed to determine the stages in the life cycle of oil and gas industry facilities, which require priority attention in terms of technological and technical improvement

Based on the analysis of the factors of emergencies, a technical solution is proposed to prevent the creation of conditions favorable to the emergencies. The system of equipment diagnostics was improved, including defectoscopy of downhole pump rods. The system allows identifying the defects of the rods and extracting them before they get into the well, thus preventing emergencies that are potential sources of environmental pollution. The flaw detector design provides for the reduction of the magnetic field scattering, which improves the flaw detector quality characteristics and allows the flaw detector to pass smoothly through the dropout at the ends of the rods and couplings.

REFERENCES

[1] C. B. Berzina, *Systemy ekolohichnoho upravlinnia. Dovidnykovyi posibnyk z vprovadzhennia mizhnarodnykh*, standartiv serii ISO 14000. K.: Aiva Plus Ltd, 2009. 62 s.

[2] M. A Khvesyk, A.V. Stepanenko, H.O. Obykhod, ta in, *Ekolohichna modernizatsiia v systemi pryrodno-tekhnohennoi ta ekolohichnoi bezpeky*. Za nauk. red. d.e.n., prof., akad. NAAN Ukrainy M.A. Khvesyka. K.: Derzhavna ustanova Instytut ekonomiky pryrodokorystuvannia ta staloho rozvytku Natsionalnoi akademii nauk Ukrainy, 455s, 2016.

[3] V.N. Chuvilov, *Prognozirovanie zagryazneniya atmosfery vozmozhnymi avarijnymi vybrosami serovodorodosoderzhashchego gaza pri stroitel'stve skvazhin na Astrahanskom GKM: dis. ... kand. geogr. nauk*: 25.00.23 A, 152s, 2002.

[4] *Directive 2009/119/EC of the European Parliament and of the Council 14 September 2009 imposing an obligation on Member States to maintain minimum stocks of crude oil and/or petroleum products*, p. 1–23, L 265/10, 9.10.2009.

[5] S.V. Berzina, I.I. Yareskovska, ta in, *Systemy ekolohichnoho upravlinnia: suchasni tendentsii ta mizhnarodni standarty*. Posibnyk K: Instytut ekolohichnoho upravlinnia ta zbalansovanoho pryrodokorystuvannia, 134 s, 2017.

[6] L.M. Stremberg, *Informacionnaya tekhnologiya analiza zhiznennogo cikla i ocenki ekologicheskoj bezopasnosti stroitel'nyh ob"ektov*: avtoref. dis. ... kand. tekh. nauk: 11.00.11. M., 2000.

[7] DSTU ISO 14040:2013 *Ekolohichne upravlinnia. Otsiniuvannia zhyttievoho tsyklu. Pryntsypy ta struktura* [Chynnyi vid 29 lystopada 2013 no. 1424]. http://online.budstandart.com/ua/catalog/doc-page?id_doc=70997.

[8] A.C. Kokossis, F. Thompson, T. K. Das, *Life Cycle Engineering in the Oil and Gas Industries, with Reference to Hydrodesulphurization of Gas Oil*, Submitted to Topical Conference: Sustainable Engineering, Paper 5c, AIChE Annual Proceedings, Austin, TX, pp. 36, 2004.

[9] V.V. Semenov, A.N. Siur, A.V. Kardykov, H.A. Chazov, A.S. № 1481668, MPK G 01 N 27/82. Sposob nerazrushaiushcheho kontrolia hlybynnonasosnыkh shtanh / Zamovnyk i vlasnyk Permskyi derzhavnyi naukovodoslidnyi i proektnyi instytut naftovoi promyslovosti. – № 4297452 / 25-28 zaiavl. 14.08.1987; opubl. 23.05.1989, Biul. №19.

[10] O. A. Poternak, I. O. Senkiv, V. I. Mykhailenko, O. I. Karpenko, Patent Ukrainy na korysnu model № 110183, MPK G 01 N 27/00, Universalna ustanovka dlia defektoskopii nasosno-kompresornykh, burylnykh trub ta hnuchkykh trub koltiubinhovanykh ustanovok., Zaiavnyk i patentovlasnyk TOV «Poltavska burova kompaniia». № u 201603808; zaiavl. 08.04.2016; opubl. 26.09.2016, Biul. № 18.

[11] M.F. Smyrnyi, D. M. Marchenko, Ye. M. Shapran, H. O. Boiko, V. A. Bihvava, Patent Ukrainy

na korysnu model № 103161, MPK V 61 K 9/00, Reikovyi mahnitnyi defektoskop. Zaiavnyk i patentovlasnyk skhidnoukrainskyi natsionalnyi universytet imeni Volodymyra Dalia. – № u 201504338, zaiavl. 05.05.2015; opubl. 10.12.2015, Biul. № 23.

[12] L. Shkitsa, T. Yatsyshyn, M. Liakh ets, *Innovative development of resourse-saving technologies for mining*. Multi-authored monograph. Sofia: Publishing House “St.Ivan Rilski”, 2018.

[13] Shkitsa L., Yatsyshyn T., Lyakh M., Sydorenko O. *Innovative approaches to the formation of environmental safety at the objects of oil and gas production*. Materials Science and Engineering: IOP Conf. Series, no. 749, 2020.

[14] V. A. Kuz'menko, *Gazo- nefte- vodoproyavleniya i otkrytye fontany v period s 1944 po 2000 gody*. Obstoyatel'stva i prichiny ih vozniknoveniya. Kiev. 2006.

[15] T. Yatsyshyn, N.Glibovytska , L. Skitsa, M. Liakh, S. Kachala, *Investigation of biotechnogenic system formed by long-term impact of oil extraction objects*, Systems, Decision and Control in Energy I. Series Volume 298, 2020.

[16] T. M. Yatsyshyn, *Otsinka zhyttievoho tsyklu yak instrument ekoefektyvnosti naftohazovydobuvnykh obiektiv*, Rozvidka ta rozrobka naftovykh i hazovykh rodovyshch, no. 3, vol 72, pp. 2019.