UDC 504.054:582.685.4 https://doi.org/10.31861/biosystems2020.01.052

THE DRILLING SOLUTION COMPONENTS' IMPACT ON THE ENVIRONMENT AND DIRECTIONS OF ITS REDUCTION

N. I. GLIBOVYTSKA, L. V. PLAKSIY

Ivano-Frankivsk National Technical University of Oil and Gas
Karpatska st., 15, Ivano-Frankivsk, Ukraine, 76000
email: nataly.glibovytska@gmail.com

The problem of the oil wells operation influence on the environmental ecological state is considered. The technical and biological aspects of the impact of drilling solution components used in the process of oil production on the biotic and abiotic environment are analyzed. The methods of preserving the cleanliness of reservoirs and soil during the wells operations and preventing pollutants from entering the environment are described. Possible effects of the toxic compounds of the drilling fluid on living organisms, in particular plants, have been identified. The components of drilling fluids of different types are characterized by different levels of environmental hazard. The lowest level of threat to environmental safety is inherent in the clay type of solution, and the polymer-potassium solution is characterized by the highest potentially dangerous impact on the biota. Despite belonging to the third class of moderately hazardous substances, sodium salts, calcium and chlorides, as components of drilling fluids, have the highest destructive effects on the environment. Soil salinization has the most detrimental effect on plants, as it breaks the osmotic equilibrium in the soil-plant system, disrupts the transport of organogenic elements throughout the plant, and reduces the availability of moisture and minerals. Increasing soil pH due to the ingress of calcium and sodium hydroxides as components of drilling fluids adversely affects plant growth and development. Stability of some groups of plants to the influence of components of drilling fluids and ability of phytoobjects to resist stress influence are noted. Halophytes are well adapted to the growth in conditions of excessive soil salinization due to the specific metabolic and structural features of the organization. Low oil content in drilling fluids can be released into the environment and, when accumulated in the aquatic and soil environments, lead to a number of destructive processes in living systems. Plants sensitive to oil pollution respond by reducing growth processes, increasing catabolic processes, and reducing assimilation function. In order to minimize the negative impact of chemicals on the environment of oil production territories, it is necessary to apply a comprehensive approach that combines the technical aspects of pollution control with effective biological methods. The urgent task of modern environmental science is to search for oil-resistant plant species that are effectively capable of converting toxic petroleum products to biota-safe compounds. Technological recommendations for the prevention of environmental pollution by drilling fluids are proposed, as well as phytorecultivation methods for controlling already polluted ecosystems.

Keywords: drilling solution, oil well, environment, chemical contaminants, phytoremediants, biological reclamation.

Introduction. Petroleum pollution is one of the global environmental problems of today. There are known destructive effects of oil on living organisms, which are manifested in the suppression of growth processes, the appearance of developmental abnormalities, death of plants and animals. The most dangerous are the aromatic hydrocarbons as components of the oil, since these compounds have mutagenic and carcinogenic action and are capable of being metabolized only in living remedial organisms. Heavy metals and compounds of sulfur, nitrogen, which are oil components, block the activity of enzyme systems in biological objects and accelerate their premature aging, are also toxic (Alves-Silva et al., 2018; Glibovytska, Karavanovych, 2018; Pedroso et al., 2016). In addition to the immediate danger of the oil itself and the oil products to the environment, the drilling fluids used in the operation of the oil wells pose a threat to the normal functioning of living systems. Drilling solution are complex multi-component dispersion systems of suspensions, emulsions and aerated liquids used for drilling wells. The toxicity of the drilling fluid and the degree of potential threat to the operational work depend on the number and hazard class of the chemical reagents included in the drilling solution.

The purpose of our work is to analyze the possible impact of drilling solution components on the environment and to find technical and biological ways of counteracting the risks of contamination by toxicants during the operation of oil wells.

The following types of drilling fluids are distinguished: clay, polymer-clay, polymer-acrylic, polymer-potassium (table. 1) (Tarasova et al., 2007).

Table 1.

Types of drilling solutions and their composition

Type of drilling solution	**Drilling solution composition**
Clay	clay powder, sodium carbonate, graphite
Polymer-clay	clay powder, carboxymethylcellulose, sodium carbonate
Polymer-acrylic	clay powder, potassium chloride, sodium carbonate, sodium hydroxide, polyanionic cellulose of high viscosity and low viscosity form, biopolymer-structure-forming agent, hydrolyzed polyacrylamide,
Polymer-potassium	clay powder, potassium chloride, sodium carbonate, sodium hydroxide, oil, high viscosity and low viscosity polyanionic cellulose, polysaccharide stabilizer, calcium hydroxide, graphite, calcium carbonate

The smallest number of components is included in the clay solution, the largest - in the polymer-potassium solution. The toxicity of the drilling solution components is uneven and is determined by the chemical nature of these components.

Chemical reagents used for drilling solutions are the next:

– clay powder – is a dried and crushed clay with or without chemical reagents;
– graphite – is a crystalline silver powder insoluble in water, obtained by flotation enrichment of natural graphite ores;
– high-viscosity and low-viscosity polyanionic cellulose –is white, odorless, water-soluble powder, used as a drilling fluid stabilizer;
– polysaccharide stabilizer – is a scattered fine, odorless white powder that is an organic polymer;
– structure-forming agent – is a biopolymer, loose, white, odorless powder, used as a structure-forming mud;
– sodium carbonate – is a white powder used to improve the quality of clay powders and clays;
– cretaceous – is a type of poorly cemented fine-grained carbonate rock used as a filler of drilling solution, characterized by a relatively small structure-forming ability and belongs to non-toxic materials;
– potassium chloride – is a crystalline substance soluble in water used as an inhibitor, which has a positive effect on the retention of the wells walls;
– hydrolyzed polyacrylamide – is a white, odorless powder used as a drilling fluid structure;
– carboxymethylcellulose – is a white or yellowish inhomogeneous powder used as a drilling fluid stabilizer;
– calcium hydroxide – is a powdery or paste-like reagent of white color, strong alkali by origin, makes it easy to adjust the structural and mechanical properties of the solution;
– sodium hydroxide – is a white crystalline mass, well soluble in water, accompanied by the release of a large amount of heat;
– calcium carbonate formed from specially treated crystalline white marble, insoluble in water, used as a weighting agent for acid-borne drilling fluid.

The characteristics of the drilling solution components are shown in table 2 (Tarasova et al., 2007).

Among these compounds, sodium and calcium hydroxides belong to the second hazard class and are characterized as highly hazardous substances. Sodium carbonate, potassium chloride, carboxymethylcellulose, hydrolyzed polyacrylamide, calcium carbonate belong to the third hazard class and are moderately hazardous substances. The fourth class includes clay powder, polysaccharide stabilizer, structure-forming agent, graphite, oil, polyanionic cellulose of high viscosity and low viscosity form.

Calcium and sodium hydroxides, entering the soil, cause an increase in the soil alkalinity, which reduces the availability of phosphorus, iron, manganese, copper, zinc and boron for plants. This disrupts the mineral nutrition of plants. Sodium and calcium carbonate, calcium chloride cause soil salinization, which reduces the availability of water to the plants and leads to their drying and premature death (Birke et al., 2018). The most toxic effects on plants are sodium and chlorine ions, which increase the osmotic potential of the soil solution, lead to impaired nitrogen and sulfur metabolism. In conditions of soil salinization the structure and functioning of chloroplasts of cells are impaired, the assimilation function of plants is suppressed, the permeability of membranes is slowed, the growth and development of plants is decreased, the level of oxidative stress is increased. In this case, free radical processes in the mitochondria during cellular respiration accelerate and damage vital structures within the cell. Particularly sensitive to the effect of salts is the generative sphere of the plant, which is manifested in the suppression of seed germination and the formation of generative cells through a number of destructive processes: disturbance of hormonal balance of the plant organism, synthesis of protein molecules, nucleic acids (Daliakopoulos et al., 2016; Machado, Serralheiro, 2017).

Table 2.

Characteristics of drilling solution components

№	Drilling solution components	Drilling solution content,%	MPC*, mg/kg of soil	Hazardous class
1	Clay powder	6.0	-	4
2	Sodium carbonate	0.3	200	3
3	Sodium hydroxide	0.2	2000	2
4	Potassium chloride	6.0	-	3
5	High-viscosity polyanionic cellulose	0.3	3000	4
6	Low-viscosity polyanionic cellulose	0.6	400	4
7	Polysaccharide stabilizer	1.2	-	4
8	Carboxymethylcellulose	0.9	3000	3
9	Hydrolyzed polyacrylamide	0.4	4000	3
10	Structural Former	0.5	8000	4
11	Graphite	2.0	0	4
12	Calcium hydroxide	2.0	8000	2
13	Oil	10.0	4000	4
14	Calcium carbonate	8.0	4500	3

Note: MPC is the maximum permissible concentration.

Most plant species belong to glycophytes - plants that are not adapted to the increased concentration of salts in soils. Therefore, an alternative biological method of combating increased salts content in oil wells is to plant halophytic plants that are resistant to soil salinization. Halophytes, which in the process of individual development have adapted to high concentrations of salts, can be divided into three groups: eugalophytes, cryptogalophytes, glycogalophytes. Eugalophytes accumulate a large amount of salts in cells without harming their body due to the high - up to 7% - concentration of salts in cellular juice, and therefore can absorb water from a highly concentrated soil solution. Cryptogalophytes absorb salts by roots, but do not accumulate salts in cellular juice, but secrete toxic matters through special cells on leaves and stems. The plants of this group are characterized by a high intensity of photosynthesis, which creates a high concentration of cellular juice, that allows the plants to absorb water from saline soils. Glycogalophytes are characterized by the fact that the cytoplasm of their root cells is poorly permeable to salts, so they do not enter the plant. High osmotic concentration in the cells of this plants group is caused by the intense photosynthesis and accumulation of soluble carbohydrates. All groups of halophytes have pronounced adaptation features of physiological and biochemical processes. In particular, they have an accumulation of so-called protective substances, which make the cells more resistant to high salt concentrations. At salinization, the genes encoding the enzymes of proline and betaine synthesis, enzymes of lignin synthesis, as well as encoding protective proteins, aquaporins, various ATPases and proteases begin to express. The use of plants with resistance to soil salinization may be the basis of phytoremediation technologies for the restoration of man-made ecosystems (Derkach, Romaniuk, 2016; Nouri et al., 2017; Negrão et al., 2017).

Oil, which is part of the drilling fluid at the highest concentration relative to other components, has a stimulating effect on plant growth in its low content in environment. However, accumulating in the ecosystem, petroleum compounds have a detrimental effect on living systems. Today, the restoration of oil-contaminated territories using environmentally safe biological methods is one of the priority areas of environmental science. In particular, plants characterized by valuable metabolic indicators convert toxic aromatic hydrocarbons to biota-harmless products - water and carbon dioxide - are widely introduced into the greening of oil production areas. A separate group is formed by plants that absorb heavy metals present in large quantities in oil. Such plants are resistant to heavy metals because they inactivate them in fixed forms, blocking the ability of metals to interact with the components of plant cells. The main mechanisms of protection of a plant organism from the influence of heavy metals are the synthesis of phytochelatins, metallothioneins, the transport of metals in vacuoles and lysosomes, the binding of metals to the cell wall of plants. The availability of heavy metals to plants is due to their transition from insoluble to soluble form in soil, which is accelerated by soil acidification (Cristaldi et al., 2017; Kaur et al., 2017; Ikeura et al., 2016; Musilova et al., 2017; Li et al., 2018; Lim et al., 2016; Shevchyk, Romanyuk, 2017).

Polymers included in the drilling solution - high-viscosity and low-viscosity polyanionic cellulose, hydrolyzed polyacrylamide, carboxymethylcellulose, polysaccharide-stabilizer, structure-forming agent do not exhibit pronounced toxic effects on the environment, and small amounts of graphite and clay do not disturb the physical and chemical structure of the soil.

In large quantities, drilling fluids pose environmental hazards to water and soil. During excavation, transportation, mechanical damage to the soil is observed, which, in combination with chemical contamination of the drilling solution components, contributes to the degradation of edaphotopes. Therefore, when constructing drilling rigs, installation, dismantling of drilling equipment, it is necessary to take measures that exclude contamination of areas by metal, reinforced concrete, wood and other materials. Technological and emergency causes are the sources of drilling solutions' components entering the environment. Technological reasons include non-compliance with drilling solutions safety rules, groundwater contamination due to leakage of columns and poor cementing, pipeline breaks, violations of transportation and storage requirements for drilling fluids. Emergency causes arise as a result of the breach of the well test technology mentioned above. Environmental measures aimed at preventing possible causes and ways of environmental contamination during the operation of wells should be aimed at eliminating sources of pollutants and the consequences of their negative effects, and in case of environmental impact, drilling solution components should not exceed the maximum permissible concentrations in the environment. During wells drilling is not allowed to disrupt technological processes that can lead to open fountain accidents. Before the well operations they must have a contingency plan with clearly defined responsibilities for each drill crew member, instructions for preventing appropriate services, a list of necessary equipment and reagents. Delivery of drilling fluids to the well must be carried out in sealed containers and stored in an equipped warehouse, the fuel supply to the engines must be done through a sealed pipeline, collection and removal of waste drilling fluids must be carried out in special metal containers. Well development products must be treated and disposed of in sludge barns with an anti-filtration screen.

The well should be far from urbanized sites to reduce the negative impact of the chemical components on people.

The protection of surface water bodies and groundwater must be carried out at all stages of the well construction, taking into account construction and installation works, drilling, mounting and well testing.

Optimal technological and technical measures should be provided to ensure the environmental safety of the facility and minimize its adverse effects on the aquifer and other water bodies, namely:

- creation of a uniform cement ring at the well fixing by casing in the zones of occurrence of highly mineralized waters;
- to prevent the migration of groundwater and reservoir fluids, all casing columns are cemented by raising the slurry;
- when drilling under the service column on the wellhead, the ejection equipment is installed;
- the use of chemical reagents of the 3rd and 4th class of toxicity in the washing and tamponing solutions.

These measures provide protection of fresh and mineral waters from: penetration of surface pollutants, contamination by drilling fluids components, ingress of formation fluids in the environment in emergency situations. To prevent leakage of drilling fluids during starting and lifting operations, special drainage devices must be used.

Conclusions. The most dangerous components of the drilling fluid are sodium hydroxide, calcium hydroxide, leading to a strong shift of soil pH towards alkaline. Potassium chloride, sodium carbonate and calcium are also known to have toxic effects on the biota, as they cause soil salinization, reduce the availability of water and nutrients to plants, impair the integrity and functioning of the plant organism. Other components of oil do not have a significant toxic effect on the biota, because they are polymers of natural origin or minerals. In order to prevent pollution by drilling fluids, a number of technological measures and observance of safety rules are envisaged, as well as the use in the landscaping of oil production territories resistant to possible contamination of plant species.

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ВПЛИВ КОМПОНЕНТІВ БУРОВОГО РОЗЧИНУ НА ДОВКІЛЛЯ ТА НАПРЯМИ ЙОГО ЗМЕНШЕННЯ

Н. І. Глібовицька, Л. В. Плаксій

Розглянуто проблему наслідків розробки нафтових свердловин з екологічної точки зору. Проаналізовані технічні та біологічні аспекти впливу складових бурових розчинів, що використовуються у процесі нафтовидобутку, на біотичне та абіотичне середовище. Описано методи збереження чистоти водойм та ґрунту при експлуатації свердловин та запобігання потрапляння забруднювачів у довкілля. Виявлено можливий вплив токсичних сполук бурового розчину на живі організми, зокрема рослини. Охарактеризовано компоненти бурових розчинів різних типів, які відрізняються рівнем екологічної небезпеки. Найменший рівень загрози для безпеки довкілля притаманний глинистому типу бурового розчину, а полімер-калієвий буровий розчин характеризується найвищим потенційно небезпечним впливом на біоту. Незважаючи на приналежність до третього класу помірно-небезпечних речовин, встановлено найвищий деструктивний вплив на довкілля солей натрію, кальцію та хлоридів як компонентів бурових розчинів. Засолення ґрунту найбільш згубно впливає на рослини, оскільки порушується осмотична рівновага у системі «ґрунт-рослина», порушується транспорт органогенних елементів по рослині, зменшується доступність вологи та мінеральних речовин. Підвищення показника pH ґрунту через потрапляння у нього гідроксидів кальцію і натрію як компонентів бурових розчинів несприятливо впливає на ріст та розвиток рослин. Відзначено стійкість деяких груп рослин до впливу *компонентів бурових розчинів та здатність фітооб'єктів протидіяти стресовому впливові. Галофіти є добре пристосовані до зростання в умовах надмірного засолення ґрунту завдяки особливим метаболічним та структурним особливостям організації. Невеликий вміст нафти у бурових розчинах може потрапляти у довкілля та, накопичуючись у водному та ґрунтовому середовищі, призводити до низки деструктивних процесів у живих системах. Чутливі до нафтового забруднення рослини реагують зниженням ростових процесів, посиленням катаболічних процесів, зниженням асиміляційної функції. З метою мінімізації негативного впливу хімічних речовин на довкілля територій нафтовидобутку необхідно застосовувати комплексний підхід, що передбачає поєднання технічних аспектів захисту від забруднення з ефективними біологічними методами. Актуальним завданням сучасної екологічної науки є пошук стійких до нафтового забруднення видів рослин, які ефективно здатні перетворювати токсичні нафтопродукти до безпечних для біоти сполук. Запропоновано технологічні рекомендації для запобігання забрудненню довкілля буровим розчинами, а також фіторекультиваційні способи боротьби з уже забрудненими екосистемами.*

Ключові слова: буровий розчин, нафтова свердловина, довкілля, хімічні забруднювачі, фіторемедіанти, біологічна рекультивація

Отримано редколегією 19.04.2020