

# Environmental risks in the application of hydraulic fracturing technology in the oil industry

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**Abstract.** Various environmental risks associated with promising hydraulic fracturing technology for carbon extraction have been studied. A comparative analysis of the use of hydraulic fracturing technology in the USA, EU countries and Russia has been carried out, and it is shown that in Europe and in the USA this technology is prohibited, not without the help of environmental activists. In Russia, some oil producing enterprises implementing similar technology when drilling wells in the Khanty-Mansiysk and Yamalo-Nenets Autonomous Districts are also implementing a modernized technology called multi-stage hydraulic fracturing. This technology makes it possible to increase efficiency in hard-to-recover oil reservoirs. The methods of hydraulic fracturing technology optimization are proposed in order to increase its efficiency and reduce environmental risks when using this technology.

## 1 Introduction

In parallel with the increase in oil and natural gas production over the past two decades, there has been increasing concern about the negative impacts of this oil and gas production process on groundwater, human health, climate and public safety, due in part to migration of methane and other gas-related volatile compounds.

The attitude towards the hydraulic fracturing method is ambiguous. Industrialists consider this the most promising technology, environmentalists are sounding the alarm, and the public reacts to all this depending on the context in which information for citizens will be presented in the media. It can definitely be said that the mixture that is used for injection into the well is a mixture of chemical reagents. It is this fact that environmental activists use, proving that these mixtures, when released into water, can cause diseases of various human organs, including the digestive and circulatory systems. However, representatives of companies, both oil-producing and service ones, claim the opposite, proving that well structure do not allow leakage of these chemicals into groundwater. The most active are environmentalists from the United States, who are seeking the closure of oil wells using hydraulic fracturing technology. In some European countries, such as France, Bulgaria, Great Britain, hydraulic fracturing technology is prohibited at the legislative level, and this is not due to groundwater

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pollution, but to earthquakes, since hydraulic fracturing technology itself involves micro-earthquake.

In Russia, environmentalists launched a large agitation campaign, as a result of which the indigenous population of the Yamalo-Nenets Autonomous District opposed the work of wells of oil and gas companies that use this technology, arguing their position by the penetration of chemicals into pastures.

## **2 Materials and methods**

The methodological research tools include scientific methods of critical analysis of literature, classification, synthesis, grouping, comparison and generalization of corporate documents of industry companies, information and analytical materials of international and Russian statistical services, relevant ministries and organizations, scientific publications on the research topic.

The research process used a systematic approach, involving the analysis of the categories of “hydraulic fracturing”, “ultra-low permeability rocks”, “BTEX connections”, “hard-to-recover reserves (TRR)” as complex phenomena that have empirical components. The method of situational statistical analysis was used to assess the volume of use of hydraulic fracturing technology by such companies as Yukos, Gazpromneft and Rosneft. Information and analytical support for the study contributed to the selection of information sources and their analysis with the identification of patterns of the research object.

## **3 Results and discussion**

Hydraulic fracturing is becoming the primary method for extracting hydrocarbons. High-pressure injection usually contains 99% of water, 0.5% of proppant (silicon dioxide) and 0.5% of chemical additives – including 7 main chemical agents of thousand that were identified by the Environmental Protection Agency, among them: crystalline silicon dioxide, ethylene glycol, hydrotreated light petroleum distillates, isopropanol, methanol, 2-n-butoxyethanol, and sodium hydroxide [1].

For several decades, hydraulic fracturing technology has been widely and widely used in the United States to extract hydrocarbons, which has had a significant impact on the economic and socio-political sphere. Every year, thousands of wells continue to be drilled in the United States, discussions about the environmental impact of hydraulic fracturing technology remain relevant, and the economic benefits of using this type of technology for oil and natural gas production remain relevant. Both proponents and opponents of this method of hydrocarbon extraction compete to influence government decisions in this area and can have a major impact on the future development of oil and gas production [2].

Russian companies such as Yukos, Gazpromneft and Rosneft use hydraulic fracturing technology in the fields of Khanty-Mansiysk and Yamalo-Nenets Autonomous Districts, for example, the largest hydraulic fracturing was in 2006 at the Priobskoye oil field, and then in 2016 it was tested a new multi-stage hydraulic fracturing technology that creates cracks in several horizontal drilling locations in the Yuzhno-Priobskoye field.

There are a large number of deposits in Russia, but it is becoming increasingly difficult to extract oil. Therefore, such a category as hard-to-recover oil has appeared, and it is precisely for such categories of oil reserves that hydraulic fracturing technology is used in order to increase the production rate of wells. But after the imposition of sanctions against Russia and its business by the countries of “the collective West”, the market for products for the implementation of hydraulic fracturing technology froze, since 90% of the equipment

was manufactured abroad, and Russian oil companies purchased this equipment. It was decided to create our own equipment for the needs of oil companies [3].

Industrial use of existing domestic developments may begin within 1-2 years. However, questions arise as to how competitive Russian equipment will be compared to its Western counterparts and what share of components will be produced in our country.

Specialists of the UfaNIPIneft, Scientific Institute of Rosneft in Ufa, have developed an innovative technology of multi-stage hydraulic fracturing (MSHF) for ultra-low-permeable rocks. MSHF is the most effective method of increasing the contact area of a well with a reservoir. It allows to maximize the inclusion of reservoir intervals that were not previously involved in development and increase oil recovery.

The depletion of the resource base of oil reserves and the need to involve hard-to-recover reserves and marginal zones of fields contribute to the development of this technology. The difference between multi-stage (MSHF) and single-stage hydraulic fracturing is that the stages are carried out alternately, cycle by cycle, somewhat with the study of rock mechanics. MSHF in horizontal wellbores is a key technology for the extraction of oil and gas from low-permeability reservoirs.

The technology of multi-stage hydraulic fracturing will make it possible to increase the productivity of wells in fields with a complex geological structure by 2-3 times. The essence of the technology is to alternately pump proppant with high and low viscosity gel into the fracture to increase its length. The technology was applied to 2 wells of the Bazhenov Shale, that is, they drilled to a depth of up to 3 km. As a result, flowing oil flows with a high flow rate of 80 and 200 tons per day were obtained, respectively, which is 2 times higher than the indicators previously obtained at similar facilities.

The results obtained showed the promise of the MSHF technology for ultra-low-permeability rocks and the potential for its further development. Pilot testing are planned to continue at another 16 horizontal wells of Rosneft fields. The potential application of the technology is more than 1 thousand wells. The development of innovation will allow increasing the production of Bazhenov oil by involving in the development of new areas for oil exploration and production throughout Western Siberia.

Gazpromneft carried out a unique hydraulic fracturing operation in the Bazhenov Shale with a record number of stages, speed and volume of fluid injected into the rock. The rate of liquid injection into the reservoir was 14 cubic meters per minute, the injection volume per stage was 2000 cubic meters, which is 3.5 and 6 times higher than the industry average, respectively. This made it possible to increase the flow of Bazhenov oil by 2.2 times.

Considering the fact that hydraulic fracturing technology, as the main technology for oil and gas production, is a relatively new technology for hydrocarbon production, and the benefits and costs it has remain uncertain, the debate continues to be relevant as to how widely hydraulic fracturing technology should be applied, and if so, in which way.

Opponents of this method of hydrocarbon production speak negatively about the consequences of oil and natural gas production using hydraulic fracturing technology. This is associated with both economic cycles of booms and busts, as well as negative impacts on public health as a result of occupational and social risks. This may include social stress caused by a violation of the sense of attachment at the place of stay; noise and air pollution, reduced light levels; excessive water consumption (especially in water-poor areas) and its pollution; increased seismic activity; severely negative impact on the environment and wildlife in the hydrocarbon production area.

Let's look at the real environmental risks that hydraulic fracturing technology poses.

1. In many developed countries, the problem of groundwater pollution is one of the main environmental issues. It is advisable to develop tools and decision-making mechanisms to properly assess the risk to human health due to toxic and chemical pollutants present in soil and groundwater. The fracking fluids used contain many hazardous substances such as

benzene, toluene, ethylbenzene and xylene BTEX compounds. BTEX compounds - benzene, toluene, xylene and ethylbenzene - were present in 60 hydraulic fracturing products used between 2005 and 2009. The US Environmental Protection Agency (USEPA) has classified BTEX pollutants as priority pollutants; they are constantly present in various water resources.

It is very difficult to observe and measure the processes of movement of groundwater flows and the distribution of pollutants underground, since this requires a large amount of time. In this regard, insufficient importance is attached to the risks of groundwater pollution. However, this problem has wide practical significance due to the frequent cases of groundwater pollution, its impact on drinking water supplies and the high costs of restoring water supplies [4].

2. As natural gas and oil production continues to increase, there is also an increase in the amount of oil and gas wastewater that can impact drinking water supplies through spills during storage or transportation, improper disposal, or discharge from wastewater treatment plants. Because conventional wastewater treatment does not remove bromides or iodides, this halide-rich wastewater combines with surface water before entering the downstream treatment plant and can contribute to increased formation of Br/I-DBP. Oil and gas industry wastewater is intriguing because, in addition to its exceptionally high bromide and iodide content, over 800 iodine-containing organic compounds have been found in (untreated) oil and gas industry wastewater, as well as numerous geogenic and synthetic compounds. There are currently no regulatory requirements for I-DBPs, despite their increased toxicity compared to brominated and chlorinated DBPs (Br-DBP and Cl-DBP) [5].

3. In order to consistently produce large quantities of oil in deep and ultra-deep formations, hydraulic fracturing technology is used in most cases. During hydraulic fracturing, a significant volume of fluid is injected into the formation. However, statistical analysis shows that the reverse flow rate is typically less than 30%, resulting in most of the fluid being trapped within the formation. Thus, hydraulic fracturing in deep formations not only increases the permeability of the formation by creating artificial fractures, but also damages the formations due to the fracturing fluids involved [6].

## 4 Conclusion

The most appropriate is to optimize the hydraulic fracturing technology using the following conditions: eliminating the propagation of microcracks in the wellbore area, improving the injection pattern, managing perforation density, improving the combination of multiple proppants, revising the well layout/spacing and discrete use of injection using fiber filaments, in order to improve SRV, distal fracture complexity and fracture conductivity in the future [7].

The need to minimize formation damage and optimize the efficiency of fracturing fluids is very important. It seems advisable to use pure liquids that have low destructive capacity and high fluidity [8]. Once the fracturing fluid penetrates the rock, it causes severe damage to the matrix due to the high salinity and high soil stress during the deep sandstone fracturing process.

To maximize the permeability of fracturing fluids in rock, fluids with high solubility and water-based chemical reactivity are required. In most cases, deep layers of granite are more fragile. When the cold liquid comes into contact with the hot rock, microcracks form. This is due to a combination of uneven particle expansion and thermal loading. In order to achieve highly effective production stimulation, it is recommended to minimize the parameters that influence formation damage.

To minimize formation damage and optimize the effectiveness of the fracturing fluids used, it is recommended to use clean fluids with the least destructive capacity and high fluidity. The process of fracturing fluid penetration into the rock during the fracturing process

of deep sandstone has serious effects on matrix damage due to the high salinity and high soil loading characteristics.

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