Safe Technologies in the Oil Industry: Opportunities and Prospects for the Use of Polysaccharide Structure-Forming Agents in Drilling Fluids

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Abstract. One of the possible ways to solve environmental problems in oil industry is the introduction of technologies that are safe for the environment. Of particular interest in this regard are technological liquids (drilling fluids) on a polysaccharide basis with use of natural polymers. The most accessible for the application of polysaccharides are starch, xanthan and guar gum, ritizan. These structure-forming biopolymers have a set of unique properties that allow to effectively manage the rheological characteristics of drilling fluids. The article analyses the results of research on the practical application of the most available biopolymers in oil production. The main characteristics of polysaccharides are considered, their influence on the efficiency of oil production is estimated. It shows the advantages of the rheological properties of drilling fluids based on xanthan gum and ritizan.

1. Introduction
In the foreseeable future, industry competitiveness will increasingly depend on the ability to quickly adapt and implement new technologies. Technological advances in reducing energy and resource costs are closely related to the requirements for reducing environmental pollution and the amount of waste from industrial processes. These criteria help to strengthen the global focus on knowledge that will enable the sustainable production of high-demand materials with the introduction of technologies that are safe for the environment [1 – 7, 10, 12]. The use of natural and / or renewable resources is crucial for many rapidly developing industrial sectors, including the oil industry [2, 4-6, 8].

2. Theoretical part
The solution of actual problems of the oil industry is aimed at creating innovative technologies in the industry, in particular, modern methods of improving oil recovery (hydrodynamic, thermal, gas, chemical, etc.). Increasing the volume of drilling structurally complex and extended wells leads to an increase in the number of complications and accidents associated with the quality of drilling fluids used. In this regard, to improve the efficiency of wells, it is important to improve the composition of drilling fluids by using new materials or special reagents.

These reagents include polymers of the polysaccharide class. As you know, in the oil industry, polymer solutions in process fluids are used to control filtration, viscosity changes, flocculation, and shale stabilization [1, 3, 5, 6, 9, 13 – 18, 33].

A wide range of natural polymers obtained from renewable natural resources (plant biomass) [4-7, 15, 23] is available for applied research and is a real alternative to synthetically obtained substances.
from non-renewable carbon-containing raw materials (oil and natural gas) [3, 18, 25]. Some of them, for example, such as xanthan and starch, are currently actively used in the oil industry, while others remain poorly studied for further use [4-6, 12-21].

Currently, in the world of oil production, the list of polymers most commonly used in the industry should include natural biopolymers (starch, guar and xanthan gum) [5, 6, 8, 19, 21] and synthetic (functional derivatives of cellulose, acrylates, acrylamides, maleic anhydride derivatives) [6, 9 -11]. There are combinations of natural and synthetic polymers obtained by inserting side chains into the structure of a natural polymer. These include hydroxypropylguar, known since the early 70s of the last century, obtained as a result of the interaction of propylene oxide with guar gum [25]. Similarly, such reagents are obtained by modification of various polysaccharides, such as cellulose, as a result of polymeranalogical transformations [17, 25, 28]. Exopolysaccharides are also actively used in the oil industry [4, 22, 24].

3. Study of comparative characteristics of biopolymers

It is known that industrially "useful polysaccharides" have historically been obtained from algae and plant sources. The production of starch, the first polymer used in drilling fluids since 1939, has been known since the middle ages [17, 25, 27]. The main source of starch used in oil production is corn. The constant renewability and scarcity of raw materials still leave the leadership of this polymer in the price segment. In comparison with starch, guar gum is a polysaccharide obtained from the seeds of the legume plant guar (Cyanaposistetragonolobus). This polysaccharide is cultivated in all parts of the world in suitable climates, but its purchase price exceeds the cost of starch twice. Subsequently, some biopolymers, such as, for example, xanthan gum and the currently actively implemented biopolymer ritisan (a domestic polymer) were successfully synthesised in the laboratory by bacterial strains-producers of Xanthomonas campestris and Acinelobacter with Azotobacter, respectively [4, 19, 24, 29, 30]. Currently, ritisan is an economic outsider among biopolymers [4, 24].

Consideration of the chemical structure and some properties of polymer molecules (table) shows that higher viscosity values of ritizan and xanthan in comparison with guar gum and starch are due to a more branched structure of ritizan and xanthan molecules, respectively. In solutions of such polymers, side chains surround the main part of the molecule, thereby ensuring the stability of the polymer structure, and, consequently, the ability to work under extreme conditions [15, 23, 30 - 34]. As can be seen from the table, the most extensive biopolymers xanthan and ritisan operate in a wide range of pH, withstand higher temperatures, which allows the use of these polymers in difficult drilling conditions.

Numerous studies have shown that biopolymers have a set of unique properties, the main of which is the ability to effectively manage the rheological characteristics of drilling fluids [1, 2, 19, 20, 21, 31, 34]. Biopolymer solutions are characterized by a pseudo-plastic flow regime, which is manifested in the fact that the viscosity properties of polymer solutions largely depend on the shear rate. In the range of shear rates typical for flow in the annulus, the polymer solution has an increased viscosity, which contributes to a more complete removal of the drilled rock to the surface and increases the stability of the well walls, due to the adsorption of the polymer on the rock [1, 24, 31-33].

All the structure generators considered in this paper are characterized by high viscosity at low shear rates. It was established experimentally that at low values of the shear rate the viscosity of guar gum’s solution is 15 times lower than the viscosity of xanthan gum; the viscosity of xanthan gum is inferior to the viscosity of ritizan under the same conditions by 1.5 times [2, 8, 14, 21, 34, 35]. The following dependence of the effective viscosity of structure-forming agents at low shear rates is determined: \[ \text{starch} < \text{guar gum} < \text{xanthan gum} < \text{ritizan}. \] The low toxicity of all polymers corresponds to world economic standards.
### Table 1. Relationship between the structure of biopolymers, their properties and functions in oil production.

| №  | Polymer | Chemical structure (fragment of a molecule) | Thermostability | Operating pH range | Function(s) in oil production | Toxicity class |
|----|---------|---------------------------------------------|-----------------|--------------------|--------------------------------|----------------|
| 1  | Starch  | ![Starch_structure](#)                         | Destroyed at 90°C | > 12               | Reduction filter, stabilization of oil shale | 4              |
|    |         | ![Starch_image](#)                             | The resulting product affects the viscosity, but does not have a sealing effect on the filtration crust |                    |                                 |                |
| 2  | Guar gum| ![Guar_gum_structure](#)                        | Decomposes at 65°C, which limits use in deep wells | In high pH conditions | Reduction filter, increasing the stability of the wellbore, hydraulic fracturing | 4              |
| 3  | Xanthan gum | ![Xanthan_gum_structure](#) | Thermostability up to 120°C | In wide range | Increased viscosity, load-bearing capacity | 4              |
| 4  | Ritizan | ![Ritizan_structure](#)                         | Destroyed at 120°C and above | In wide range | Increased viscosity, load-bearing capacity | 4              |
4. Conclusions
In the modern oil industry, natural structure-forming biopolymers are actively used as part of drilling agents of both - the first generation (starch, xanthan, guaran) and the second generation - combined on the basis of natural and synthetic polymers, such as the modern Russian biopolymer ritizan. Due to the structural complexity of ritizan, its polymer solutions are stable in harsh temperature conditions, have increased viscosity and adsorbability on well rocks. But, despite these advantages, in comparison with other polymers, its mass use as a technological additive to drilling fluids is limited by high cost.

Thus, safe technologies in the oil industry in terms of production of hydrocarbon primary products are associated with the prospects of searching for and/or developing affordable low-cost methods for obtaining polysaccharide structure-forming agents as reagents for the production of drilling fluids based on non-toxic natural polymers.

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