A Green, Natural, Efficient, and Low-Cost Biopolymer as a Shale Swelling Inhibitor for Drilling Muds

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ABSTRACT

The wellbore instability during drilling by the expansion of the shale formations costs a lot of time and money. Several approaches are reported in the literature to reduce shale expansion such as the use of inorganic salts, PHPA, silicates, and oil-based drilling fluids. However, there are constraints connected with these solutions, including thermal instability, restricted availability, environmental and marine life toxicity, etc. In our present study, Arabic gum was exploited as a fluid loss controller and shale swelling inhibitor in water-based drilling fluids. Arabic gum is a water-soluble complex blend of polysaccharides and proteins. The branched chains of polysaccharides demonstrate a neutral or slightly acidic nature. Sudan is the world's leading producer and exporter of Arabic Gum, producing over 80 % of the yearly needs. Arabic Gum is a natural product that is utilized in a variety of items, including adhesives, medicines, inks, and foods. The detailed literature survey demonstrated the fact that Arabic gum was never utilized as a shale swelling inhibitor for drilling fluids. In order to demonstrate the shale swelling capacity of the Arabic gum, it was procured from the local market in Dammam,

Saudi Arabia. The inhibition potential was assessed by employing linear swelling and capillary suction timer tests. Different concentrations (0.5 and 1.0 wt %) of Arabic gum were utilized for the linear swelling test. Additionally, the performance of drilling fluid was examined by a fluid loss test. The experimental outcomes revealed that the Arabic Gum prominently reduced the linear swelling of bentonite clay. It was observed that the decline in linear swelling was the function of the concentration of Arabic Gum, such as 0.5 % and 1.0 % Arabic Gum reduced the linear swelling by 26.3 % and 43.0 % correspondingly. While the CST time displayed an increase with the increase in the concentration of Arabic Gum. The addition of Arabic Gum also revealed a prominent decrease in fluid loss. After the addition of 0.5 % and 1.0 % Arabic Gum, the fluid loss declined from 13 mL to 8.0 mL and 6.4 mL respectively. From the experimental findings, it can be inferred that Arabic Gum is a strong candidate that might serve as an alternate green shale inhibitor for water-based drilling fluids..

Keywords: Water-based drilling muds, Gum arabic, Biopolymer, Green additive, Sodium bentonite, Swelling inhibition

EXTENDED ABSTRACT

Introduction

Drilling muds are used for certain objectives, namely maintaining wellbore stability, drill cuttings transporting, and cooling the drill bit (Rana et al., 2022, 2021). The water-based drilling muds (WBM) are required special treatment for fluid control, stable rheology, and swelling inhibition. Therefore, chemical additives such as polymers are added to the drilling mud to meet the drilling operation requirements (Gautam et al., 2020). In the literature, some methods such as the addition of organic salts, surfactants, ionic liquids, partially hydrolyzed polyacrylamide (PHPA), and silicates were utilized to mitigate shale expansion (Khan et al., 2018, 2023; Murtaza et al., 2020d, 2020b, 2020c; Shehzad et al., 2021). However, several restrictions are accompanied by these solutions, namely thermal instability, restricted availability, environmental issues, etc (Rana et al., 2019). The non-toxic and degradable biopolymers are becoming more favorable to scientists since the environmental constraints on drilling sites have been more strict. Shale stability, rheological properties, and filtration properties of the drilling muds are positively affected by the water-soluble biopolymers such as gums (Hamed and Belhadri, 2009).

Natural gums are considered green alternatives and were proven to improve the rheological properties and fluid loss control of water-based drilling muds (Elkatatny, 2019; Li et al., 2016; Villada et al., 2017). Stabilizers, thickeners, and emulsifiers are some of the applications of gums (Patel and Goyal, 2015). However, the utilization of natural gums in the drilling mud is negligible although it has potential benefits. Some reports in the literature prove the potential of gums to improve drilling mud rheology and fluid loss control (William et al., 2014). The current study is utilizing Gum arabic as a low-cost, efficient, and green natural biopolymer for shale inhibition of water-based drilling mud. It is a water-soluble complex mix of polysaccharides and proteins. Sudan is the world's leading producer and exporter of Gum arabic, producing over 80 % of the annual requirement. Gum arabic is a natural product that is utilized in many items, including adhesives, medicines, inks, and foods (Musa et al., 2019). It can be deduced from the literature survey that Gum Arabic was never applied to mitigate shale swelling. The inhibition potential of the gum was evaluated by conducting several standardized tests, including a linear swell test, and a capillary suction timer test. Further, fluid loss properties of the drilling muds containing Gum arabic were studied.

Materials and Methods

Gum arabic was utilized as an inhibitor of shale swelling and was bought from the local markets. Sigma Aldrich supplied NaOH, which was used to adjust the pH. Sodium bentonite (Na-Ben) clay was used to examine the performance of the developed formulations. All the solutions were mixed using deionized water.

Gum arabic comprises different saccharides, including galactose, arabinose, rhamnose, and glucuronic acid (Williams and Phillips, 2021).

Drilling Muds Mixing

For the preparation and testing of modified WBMs, the experimental procedures explained in our previous work were followed (Rana et al., 2022).

First, to prepare the base drilling mud (BM), 6 wt% of Na-Ben was added to the deionized water and thoroughly blended using a Hamilton Beach mixer. Second, to make ArG-modified drilling muds, 0.5 wt% and 1.0 wt% Gum arabic (ArG) were added to 6 wt% Na-Ben (ArGM).

To obtain homogeneous drilling mud samples, 30 minutes of vigorous stirring have been performed. In the end, NaOH was added to keep the pH at 9.

Swelling Inhibition

The capillary suction timer (CST) test assessed the drilling mud's practical inhibitory potential. In the current work, the inhibition potential of ArG was investigated using the OFITE CST instrument. This test measures the time it takes for filtrate to travel from one set of electrodes to another electrode through a filter media. The capillary suction time (CST) test was performed on several drilling mud formulations with different ArG concentrations (0.5 and 1) wt.%. The base fluid was formulated by mixing 3.0 wt% bentonite in deionized water.

A linear swell test is conducted to investigate the bentonite pellet expansion linearly in the presence of aqueous fluid of ArG by using a dynamic liner swell meter (OFITE, Inc, Houston, USA). Azeem et al. (Rana et al., 2022) described the procedure for conducting the linear swell test.

The fluid loss test is an important test that provides the details on filtrate lost by the drilling mud into the formation as well the mud cake thickness on the wall of the formation. The test was conducted using the LPLT API filter press (FANN series 300). The detailed procedure was provided in our recent publication(Rana et al., 2022). The fluid loss test was carried out at 25 °C and 100 psi of pressure.

Results and discussion

Swelling Inhibition

The capillary suction timer (CST) test evaluates the inhibition potential by measuring the flow of filtrate across the filter media (Murtaza et al., 2020a). Figure 1 shows the CST outcomes of unmodified and modified-based muds. The base mud displayed the lowest CST time that is due to the stronger binding of bentonite clay with water. However, after the introduction of ArG to the drilling mud, an increase in the CST time was observed. The CST time increases with an increase in the concentration of natural gum in the base fluid. It demonstrates that the addition of ArG reduces fluid loss, and filtrate takes a long time than the base fluid to travel from one set electrode to another. The base drilling mud resulted in 1430.8 seconds. For 0.5 and 1 wt.% concentrated solutions, the CST time was increased to 1631.2 seconds and 2365 seconds. The

gum makes a layer on the filter cake, preventing water from penetrating the filter cake and increasing the travel time.

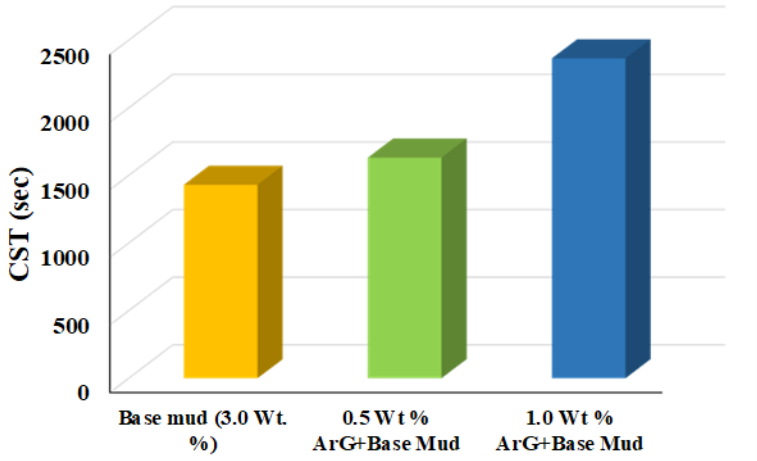

Figure-1: CST results of base mud, 0.5 Wt. % ArG+base mud, and 1.0 Wt. % ArG+base mud.

The performance of the ArG was evaluated by utilizing a linear swelling test. The clay wafer was immersed in liquid at various concentrations of the ArG for the comparison of swelling inhibition features. Figure 2 shows the linear expansion of bentonite clay in the presence of different inhibition mediums. The clay displayed the maximum swelling in the presence of deionized water i.e. 119.4 %. The addition of 0.5 wt. % ArG reduced the swelling by 26.1 %. Increase in concentration of ArG up to 1.0 wt. % further reduced the linear expansion to 76.6 %.

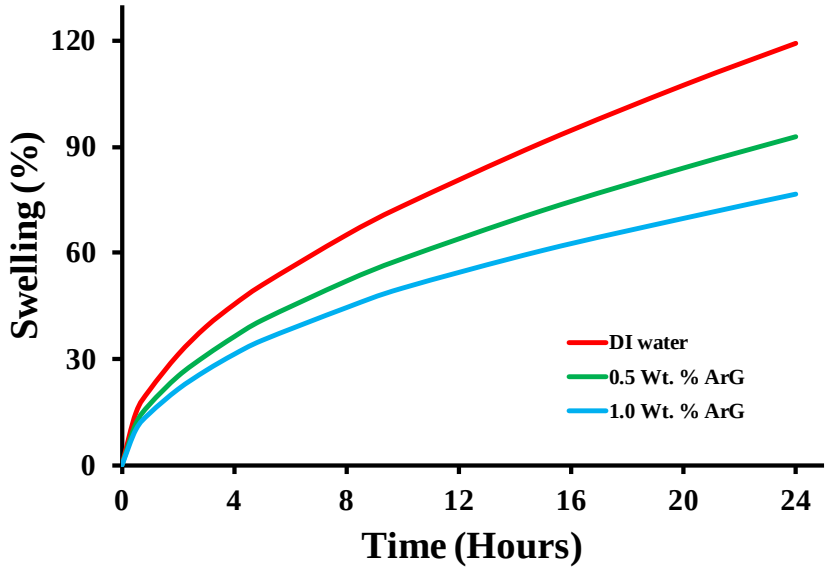

Figure-2: Linear swelling test results of base mud, 0.5 Wt. % ArG+base mud, and 1.0 Wt. % ArG+base mud.

The fluid loss test was conducted to evaluate the potential of ArG as a fluid loss controller and its impact on the drilling mud performance. Figure 3 provides the results of the base fluid and modified drilling muds. The base drilling mud showed very high fluid loss i.e. 13 mL after 30 minutes. The addition of ArG to the base fluid appreciably reduced the fluid loss. The outcomes revealed that fluid loss control is dependent on the concentration of ArG. The fluid loss reduces from 13.0 mL to 8.0 mL and 6.4 mL after the addition of 0.5 wt. % ArG and 1.0 wt. % ArG respectively. The reduction in fluid loss showed the inhibition potential of ArG. The low fluid loss into the shale formation provided low water availability to the shale for its hydration and dispersion.

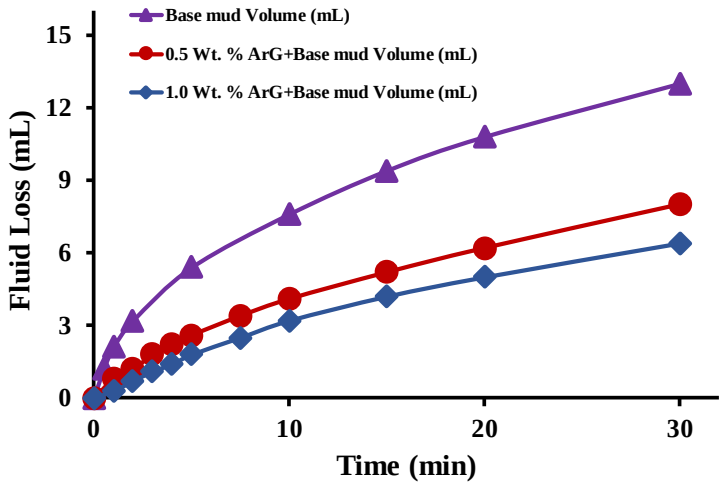

Figure-3: Fluid loss results of base mud, 0.5 Wt. % ArG+base mud, and 1.0 Wt. % ArG+base mud.

Conclusion

The prime objective of the current study is to demonstrate the swelling inhibition capacity of green, low-cost, and plant-based natural biopolymer. The linear swelling test confirms that the swelling inhibition feature of ArG depends on its concentration. The 0.5 wt. % ArG and 1.0 wt. % ArG decreases the clay swelling by 22.5 % and 36.1 % respectively. Better fluid loss control was observed when ArG was added to the base mud. The fluid loss of the base mud drops from 13.0 mL to 8.0 mL and 6.4 mL when 0.5 wt. % ArG and 1.0 wt. % ArG were added to base mud, correspondingly. Consequently, ArG can be utilized as a WBM additive that is a natural biopolymer with low environmental impact, cost-effective, frequently available, and has better clay swelling inhibition properties. The mentioned features make the ArG potentially the great candidate as a shale inhibitor for the WBM.

Acknowledgement

The authors would like to acknowledge the support of College of Petroleum Engineering & Geosciences in conducting this research.

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