SHORT COMMUNICATION

DOI: https://doi.org/10.18599/grs.2018.4.355-358

Evaluation of mineral and organic inhibitor effects on bentonite clay

F.V. Degtjarjov
Production association "Belorusneft" BelNIPIneft, Gomel, Republic of Belarus
E-mail: f.degtyarev@beloil.by

Abstract. The supra-salt complex of the oilfield of the Republic of Belarus is represented by high-colloidal multicolored clay deposits with layers of unstable sandstones and aleurolites evenly distributed throughout the section. Drilling of intervals which are represented by clay sediments is accompanied by complications caused by swelling of clays – stuck, tightening, sticking clay on the drilling tool. Swelling occurs during drilling of high-colloidal clays. As a result of the action of the drilling mud and its filtrate, the clay swells, narrowing the trunk and reducing the stability of the walls of well. For the prevention or maximum reduction of the intensity of the swelling the drilling mud must have a high inhibitory ability. Such properties are attached by special reagents-inhibitors, which are the main component of the inhibiting drilling fluid. The creation of such drilling fluid is advisable to start with the choice of the reagent-inhibitor.

This article provides a comparison of the inhibitory effect of the two reagents specific to organic (Polyekol) and inorganic (potassium chloride) compounds. To assess the effectiveness of these reagents, the indicator of moisturizing ability was used. In the experiment, the highest efficiency demonstrated organic reagent-inhibitor Polyekol at a concentration of 2%, and the inorganic reagent-inhibitor potassium chloride resulted in cracking of samples. The results obtained during the comparison of these reagents will form the basis for the development of an inhibiting drilling mud for drilling of the supra-salt deposits of the Pripyat trough.

Keywords: clay, swelling, complications, wellbore stability, reagents-inhibitors, drilling mud, indicator of moisturizing ability

Recommended citation: Degtjarjov F.V. (2018). Evaluation of mineral and organic inhibitor effects on bentonite clay. *Georesursy = Georesources*, 20(4), Part 1, pp. 355-358. DOI: https://doi.org/10.18599/grs.2018.4.355-358

The supra-salt complex of the oilfield of the Republic of Belarus is represented by high-colloidal multicolored clay deposits with layers of unstable sandstones and aleurolites evenly distributed throughout the section. When drilling oil wells, the swelling of clay rocks can cause a large number of complications, such as drilling tool sticking, cavern formation, sloughing hole, borehole enlargement and keyseating, oleaginization, loss of circulation (Sereda, Soloviev, 1974). Swelling occurs during the drilling through high colloidal clays. As a result of the washing fluid and its filtrate activity, the clay swells narrowing the borehole and reducing the stability of the borehole walls. To prevent or minimize the intensity of swelling, the drilling fluid should have high inhibition properties. Such properties can be achieved by use of special inhibitor reagents, which are the main component of the inhibitory drilling mud. Creation of such a drilling fluid is advisable to start with the selection of inhibitor reagent.

© 2018 F.V. Degtjarjov. Published by Georesursy LLC
This is an open access article under the CC BY 4.0 license (https://creativecommons.org/licenses/by/4.0/)

As an inhibitor reagent can be used a substance of both organic and inorganic nature, and their mixture. Currently, there are a huge number of such reagents available on the market. This article compares the inhibitory effect of two reagents related to organic (Polyecol) and inorganic (potassium chloride) compounds. The results obtained during the comparison of these reagents will form the basis for further development of an inhibiting drilling fluid, which can be used to drill over-salt sediments of the Pripyat trough.

The use of potassium chloride while drilling as an inhibitor of clay sediments in the territory of the Republic of Belarus has many years of experience. This reagent is included in the formulation of many drilling fluids as a clay-swelling inhibitor. However, with the development of production technologies and the creation of new research methods, a huge number of new inhibitor reagents belonging to other classes of chemicals have appeared. Therefore, in order to select the most effective reagent, it is necessary to conduct comparative tests.

The differences of inhibitor reagents belonging to different classes of chemical compounds are related to their structure, hydration principle and the action mechanism they have on clay minerals. To select the most effective inhibitor, it is necessary to accurately represent both the structure of clay minerals and the mechanism of their hydration.

According to the articles (Biletskij, Kasenov, Sushko, 2013), clay microstructure is represented by elementary plate packs with a small (fraction of micrometers) thickness and a relatively very large surface. It corresponds to a high surface energy manifested in the form of a negative electric charge. Negatively charged plates repel each other combining into packets using positive metal ions. The higher the positive charge (valence) of metals, the stronger the connection of elementary plates in the package. For example, sodium and calcium clays can be identified by the type of metal predominating in them, and the second one (containing bivalent Ca^{2+}) dissolve worse than the first one (containing monovalent Na^{+}).

During the drilling of clay rocks, the drilling fluid or its water filtrate rushes through fractures and pores into the borehole walls and comes into contact with the clay structures. It is known that the H_2O water molecule has an elongated shape, with a positive hydrogen ion concentrated at one end (the pole of the «dipole»), and a negative oxygen ion at the other. In the course of Brownian motion with clay packages, the dipoles with their positive side stick to the negatively charged surface of the plates. The surface of the elementary plates is completely «seated» by equally oriented dipoles of water i.e. covered with a «hydrated shell». With a high charge of plate, the hydration shell can thicken building on itself all new layers of water dipoles. Hydration shells moving apart the plates in the package overcoming the retention effect of metal ions. At the macroscopic extent, the hydrated shells thickening results in an increase in the volume («swelling») of clay adjacent to the well. Shear fractures appear between the swelling layer making up the borehole walls and the main «dry» rock causing collapses of the swollen material, which then accumulates in the narrowed sections of the wellbore (Biletskij, Kasenov, Sushko, 2013).

The use of inhibiting drilling muds has been recognized as the most effective method to prevent borehole walls instability. Such solutions transform easily-dissolved clay in the near-wellbore zone into difficult-to-dissolve clay. Such drilling muds necessarily contain an inhibitor reagent. The action of such reagents is based on cations adsorption on the clay surface and osmotic pressure. Osmotic pressure results from the fact that the flushing fluid has a higher concentration of cations, compared to the rock, stimulating the flow of water from the rock into the drilling fluid and, as a result, reducing the hydration of the rock (Egorova, 2010).

Inorganic compounds, in particular sodium and potassium chlorides, are widely used to reduce the penetration of water into the space between the layers of clay minerals. These compounds undergo electrolytic dissociation into positive and negative ions in solution. Positive ions neutralize the negative charge of the elementary clay plates. Their hydrated shells are thinned down to complete dissolution. The plates are connected to each other reducing the occupied volume. With the help of inhibitors, it is possible to prevent swelling of clay borehole walls, cavern formation and the associated complications (Biletskij, Kasenov, Sushko, 2013).

Organic inhibitors are considered relatively expensive. For this reason, they are commonly used in tandem with inorganic salts of sodium and potassium, herewith causing synergistic effect (Masalida, 2017). In this paper, we compared effectiveness of the following inorganic and organic reagents and their mixtures as clay swelling inhibitors:

1. Polyecol (SPC “Policell”) is a complex action organic reagent designed to improve the inhibiting, lubricating and anti-wear properties of process liquids used in drilling and well workover operations. The main active ingredient is ethylene glycol ethers.

2. Potassium chloride is an inorganic clay and shales inhibitor commonly used to drill clay sediments in concentrations from 1 to 10%.

The indicator of wetting ability (P_0, cm/h) (Uljasheva, 2008; Koshelev, Gvozd et al., 2015; Sulakshin, Chubik, 2011), is used for the purpose of a scientifically based selection of reagents for inhibiting drilling solution used in drilling of clay sediments (Povzhik, Degtyarev, 2017).

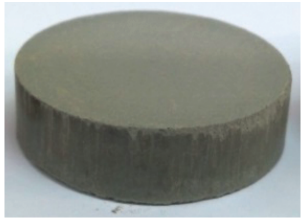
Preparation and the experiments consisted in pressing under pressure of 40.0 MPa dried to a moisture content of 8-10% and crushed to a size of 20-200 microns of a model clay material (Fig. 1), preliminary weighing and aging of compressed tablets in test media for 1 hour followed by measuring the weight of the moistened samples.

PBMV bentonite was used as a model clay material. This material contains at least 70% of the montmorillonite mineral (Grim, 1956), which due to its layered structure gives bentonite strong swelling properties in case of its contact with water. In addition, PBMV bentonite is modified with sodium carbonate. This process replaces the exchange cation in the interlayer space of the clay mineral with sodium, causing further increase in its reactivity (Bortnikov, 2012).

Thus, PBMV bentonite has both high ability to swell, and the constancy of the composition, which allows it to be used as a model for determining reagents inhibiting properties. It should be noted that the use of a single modeled clay material is necessary to eliminate the data unreliability associated with the difference in the compositions and properties of different clays.

The inhibitory effect of a drilling mud largely depends on its rheological properties. The biopolymer system

Fig. 1. Pressed bentonite mud powder sample



characterized by the highest values of conventional and plastic viscosity, static and dynamic shear stress, demonstrates the best effect on stabilizing the clay sample (Saltykov, 2008; Zamulin, 2015; Kister, 1972). In this regard, a structurant xanthan gum (MHF80PLUS Zibo Hailan Chemical Co., Ltd.) was used to simulate the rheological characteristics of the drilling fluid under the experimental conditions (Povzhik, Dobrodeeva, Degtyarev, 2017).

A 0.25% solution of xanthan biopolymer was prepared and treated with inhibitors at concentrations of 1 and 2% for Polyecol and 2.5 and 5% for KCl, as well as their mixtures. A 0.25% xanthan biopolymer solution without additives was used as a reference solution. Compressed tablets were aged in the test media for 1 hour. All experiments were conducted in three repetitions; Figure 2 shows the averaged experimental results.

According to Figure 2, in solutions with KCl in any of the studied concentrations occurs an increase in the current rate of moistening of the samples by 1.57-1.79 times as compared with the reference solution. The identified strong cracking of the compressed tablet (Fig. 3A, B) may indicate the absence of an inhibitory effect in the experimental conditions.

The increase in the moistening rate during the experiment, i.e. the absorption of water by a clay sample in a solution of an inorganic inhibitor (in this case KCl), is due to the fact that the clay does not contain filtrate in its pores. This makes the inhibitory effect of osmotic pressure impossible, while the adsorption of potassium cations on the clay surface plays a minor role in this experiment. Initially, the clay becomes saturated with liquid with its further swelling, and since the solution is also enriched with cations, then its reactivity increases. As a result, the clay sample hydration rate also increases (Masalida, 2017). It was noted that water absorption

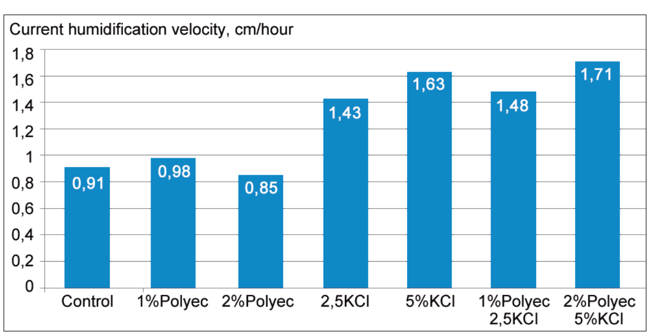


Fig. 2. Current compressed samples moistening rate

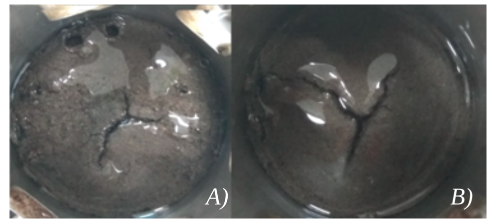


Fig. 3. Pressed samples after 1 hour in a 0.25% solution of xanthan biopolymer with a KCl content of 2.5% (A) and 5% (B)

intensity depends on the concentration of metal cations. When using solutions unsaturated with salts, an increase in the clay sample occurs gradually (in a 2.5% solution of potassium chloride, the sample moistening rate increases 1.57 times as compared with the reference solution), unlike in case of more concentrated solutions (in a 5% solution of potassium chloride sample moistening increases 1.79 times compared with the reference solution).

The best results were obtained in a solution with a Polyecol content of 2% causing decrease in the sample moistening rate by 6.6% (Fig. 4A, B). After being in Polyecol solutions, the compressed tablets have small cracks and more friable surface than after being in potassium chloride solutions. The effectiveness of Polyecol under experimental conditions is explained by the fact that, as a surfactant, it forms stronger hydrogen bonds with the clay mineral thus displacing water from the interlayer space.

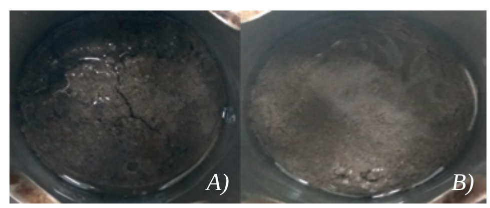


Fig. 4. Pressed samples after 1 hour in a 0.25% solution of xanthan biopolymer with a Polyecol content of 1% (A) and 2% (B)

Conclusions

Inorganic inhibitor solutions (in this case, KCl) in contact with a dry clay sample cause its disruption, since the studied clay does not contain filtrate in its pores. The clay is initially saturated with liquid, and the sample is cracked due to the wedging pressure.

A biopolymer base (xanthan gum at a concentration of not less than 0.25%) with Polyecol organic inhibitor (concentration of 1.5-2%) is well suited to stabilize clay sediments. Under the experimental conditions, there is no synergistic effect from the use of inorganic and organic inhibitors.

These studies allow us to determine the direction of further studies on creating an inhibiting drilling mud formulation for drilling oversalt sediments of the Pripyat trough.

References

Bileckij M.T., Kasenov A.K., Sushko S.M. (2013). The practice of inhibiting drilling muds application for the purpose of preventing geological aggravations while penetrating bulging clays. *Vestnik Kazahskogo nacional'nogo tehnicheskogo universiteta imeni K.I. Satpaeva* [Bulletin of the Satpayev Kazakh National Technical University], 3(97), pp. 16-22. (In Russ.)

Bortnikov S.V. (2012). Activation of alkaline-earth bentonite by sodium carbonate. *Al'manah sovremennoy nauki i obrazovaniya* [Almanac of modern science and education], 2(57), pp. 61-63. (In Russ.)

Egorova E.V. (2010). Razrabotka ingibiruyushchego burovogo rastvora dlya bureniya v glinistykh otlozheniyakh [Development of inhibitory drilling mud for drilling in clay sediments]. *Avtoref. dis. kand. tehn. nauk* [Abstract Cand. tech. sci. diss.]. Astrahan, 194 p. (In Russ.)

Grim R.E. (1956). Clay mineralogy. Moscow: Foreign Literature Publ., 457 p. (In Russ.)

Kister Je.G. (1972). Chemical treatment of drilling muds. Moscow: Nedra Publ., 392 p.

Koshelev V.N., Gvozd' M.S., Rastegaev B.A., Ul'shin V.A., Fatkullin T.G. (2015). The choice of a solution for drilling up clay rocks. *Burenie i neft' = Drilling and oil*, 9, pp. 27-32. (In Russ.)

Masalida I.V. (2017). Study of the inhibiting properties of organic and inorganic reagents in polymer-clay drilling mud. *Problemy geologii i osvoeniya nedr: trudy XXI Mezhd. simpoziuma im. ak. M.A. Usova* [Problems of geology and subsoil development: Proc. XXI Int. Symp. named after ac. M.A. Usov]. Tomsk: TPU publ., v.2, pp. 506-508. (In Russ.)

Povzhik P.P., Dobrodeyeva I.V., Degtyarev F.V. (2017). The study of physico-chemical properties of clay-containing samples with the aim of selecting reagents-inhibitors of clay hydration. *Oborudovaniye i tekhnologii dlya neftegazovogo kompleksa = Equipment and technologies for oil and gas complex*, 4, pp. 21-24. (In Russ.)

Povzhik P.P., Degtyarev F.V. (2017). Laboratory testing of clays inhibitors and selecting of the optimal reagent for troubleproof drilling of supra-salt part of the Pripyat trough. *Oborudovaniye i tekhnologii dlya neftegazovogo kompleksa = Equipment and technologies for oil and gas complex*, 6, pp. 4-8. (In Russ.)

Saltykov V.V. (2008). The theory and practice of opening high clay terrigenous reservoirs for oil and gas with biopolymer solutions. *Avtoref. dis. dokt. tehn. nauk* [Abstract Dr. tech. sci. diss.]. Tyumen, 43 p. (In Russ.)

Sereda N.G., Solov'ev E.M. (1974). Drilling of oil and gas wells. Moscow: Nedra Publ., 455 p. (In Russ.)

Sulakshin S.S., Chubik P.S. (2011). The destruction of rocks during exploration. Tomsk: TPU publ., 367 p. (In Russ.)

Uljasheva N.M. (2008). Tehnologiya burovyh zhidkostey [Technology of drilling muds]. Uhta: UGTU, 164 p. (In Russ.)

Zamulin P.V. (2015) Types of drilling muds. The development of polymer-containing drilling muds, their features and advantages over the other solutions. *Sovremennye problemy gidrogeologii, inzhenernoj geologii i gidrogeojekologii Evrazii: materialy Vserossijskoj konferencii* [Modern problems of hydrogeology, engineering geology and hydrogeoecology of Eurasia: Proc. All-Russian Conf.]. Tomsk: TPU publ., pp. 591-596. (In Russ.)

About the Author

Filipp V. Degtjarjov – PhD student, Engineer, Drilling Fluids Service

Production association "Belorusneft" BelNIPIneft

15b, Knizhnaya st., Gomel, 246003, Republic of Belarus

Manuscript received 10 July 2018;
Accepted 17 October 2018;
Published 30 November 2018