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INFLUENCE OF IONIC HYDRATION INHIBITORS ON TRIPLE INHIBITION SYSTEM MUD PROPERTIES – CLAY ROCK SWELLING**

1. INTRODUCTION

A major problem during drilling clay rock is its swelling under influence of the mud filtrate. In relation to this, for clay rock drilling it is applied mud with inhibition system. Based on the analysis of industrial data (amongst others mud reports), it can be concluded that recently past years, while drilling clay rock, mainly mud with triple inhibition system is applied. In the light of abovementioned fact, it can be seen growing importance of studies related to improvement and development of this type of mud formulas.

In the mud with triple inhibition system, three types of hydration inhibitors are used. The most common ones are:

- polymeric inhibitors – out of those the most popular is PHPA-type polymer (partially hydrolyzed polyacrylamide), which contains about 30% of anionic groups (–COOH),
- polyglycols – e.g. block oligomers of propylene oxide and of ethylene oxide with molecular masses of 1000–2000 atomic mass unit and with different turbidity temperature,
- ionic inhibitors – mainly K^+ ions originating from potassium chloride.

The primary goal of the ionic inhibitors is limitation of both surface and osmotic hydration of drilled clay rock. This aim can be achieved by: substitution of exchangeable clay's ions by ions with lower hydration number, maintenance of greater concentration of ions in the mud than in the formation, hydrophobation of rock surface and decrease of its wettability by the drilling mud filtrate [1, 2].

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The paper presents findings of the studies on influence of selected clay rock hydration inhibitors (KCl, K_2CO_3, HCOOK, $CaCl_2$) concentration on swelling of clay rock in the muds with triple inhibition system.

2. FORMULA OF THE TEST MUD

In order to conduct studies of ionic hydration inhibitors influence on clay rock swelling, it was composed test mud, into which afterwards were added different ionic inhibitors. General formula of the studied mud is presented in Table 1.

Table 1

Formula of the studied mud

Reagent	Concentration [%]
PAC LV	1
Starch	2
XCD	0.2
PHPA PT-123/33	0.1
Ionic inhibitor	0–7
Polyglycol	3
Bridging agent 40 μm	7

The mud was composed as a non-bentonite mud, thus it can be also applied as a drill-in fluid. In the mud as the structure-builders and agents providing proper technological parameters were applied polymers: PAC LV, modified starch and XCD biopolymer. As the hydration inhibitors there were used polyglycol and PHPA polymer which was synthesized at the laboratory of Drilling and Geoengineering Department of Drilling, Oil and Gas Faculty. The mud was weighted with carbonate bridging agent.

In the studies following ionic hydration inhibitors were applied:

Mud-0: comparative mud without ionic inhibitor.
Mud-1: KCl.
Mud-2: K_2CO_3.
Mud-3: HCOOK.
Mud-4: $CaCl_2$.

3. METHODOLOGY OF THE RESEARCH

In each case, the influence of ionic hydration inhibitor on rheological parameters, filtration and density of test mud was examined (results are presented in [3]). Moreover,

tests of composed muds influence on QSE Pellets clay samples swelling and linear swelling (LST) of the Miocene shale were conducted.

Tests of drilling mud technological parameters have been performed according to Polish and International Standards (API Spec.) [4]. Linear swelling tests have been achieved with GRACE Instrument M4600 HPHT Linear Swell Meter. Test of QSE Pellets swelling include measurement of sample initial volume, afterwards the sample was conditioned in the mud for 24 h. After this time period, second measurement was undertaken and percentage increase of the volume was calculated.

4. MUD-1 WITH KCl ADDITION

First of tested ionic hydration inhibitors was potassium chloride. Test results are presented in Figures 1 and 2.

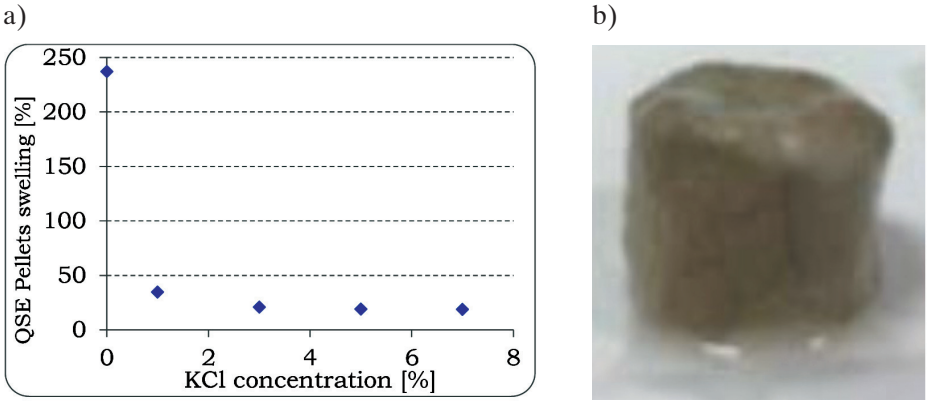


Fig. 1. QSE Pellets swelling under influence of mud with KCl addition (a), photography (b) – pellet condition for 7% of salt addition

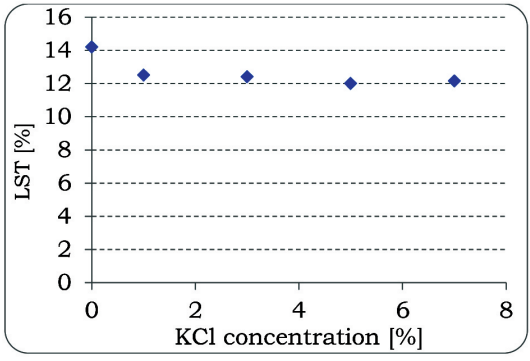


Fig. 2. Swelling (LST) of the Miocene shale under influence of mud with KCl addition

Addition of potassium chloride significantly decreases swelling of QSE Pellets even at 1% of inhibitor concentration. With KCl concentration increase it was noticed irrelevant dissimilarity in results of clay samples swelling. Mud without addition of inhibitor causes about 230% swelling of the rock sample, whereas for the mud with 7% addition of KCl, the increase of pellet volume is just about 19%.

Tests of rock samples linear swelling under influence of the muds, show only slight drop (2%) of the Miocene shale swelling after addition of 1% of potassium chloride comparing to the mud without ionic inhibitor. Further growth of the potassium chloride concentration does not lead to decrease of the samples swelling, which maintains at level of 12%.

5. MUD-2 WITH K_2CO_3 ADDITION

Graphs (Figs 3 and 4) show test outcomes of test mud with addition of potassium carbonate (K_2CO_3) as an ionic inhibitor of hydration.

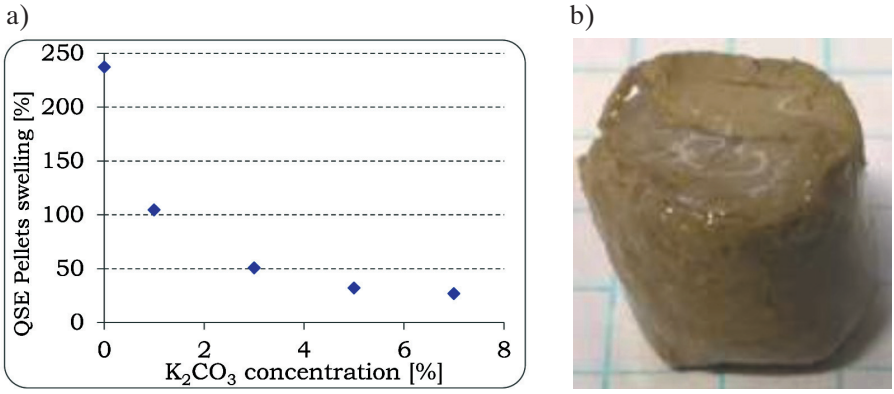


Fig. 3. QSE Pellets swelling under influence of mud with K_2CO_3 addition (a), photography (b) – pellet condition for 7% of salt addition

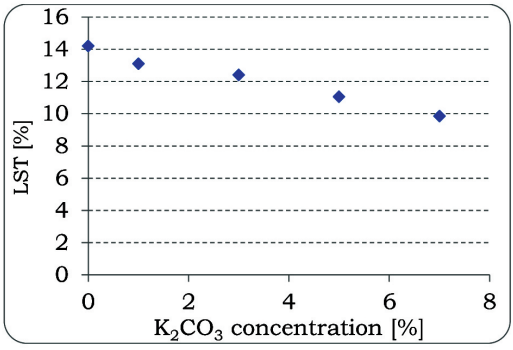


Fig. 4. Swelling (LST) of the Miocene shale under influence of mud with potassium carbonate addition

It was observed that addition of potassium carbonate at 1% concentration to the mud causes great limitation of QSE Pellets clay samples swelling. Further increase of the K_2CO_3 concentration leads to beneficial swelling decrease.

Linear swelling tests (LST) of the Miocene shale indicate that rock sample swelling decreases with the growth of potassium carbonate concentration and reaches the value of 9.85% at 7% concentration of the salt.

6. MUD-3 WITH HCOOK ADDITION

Test findings of the test mud with addition of HCOOK as an ionic hydration inhibitor are presented in Figures 5 and 6.

a) b)

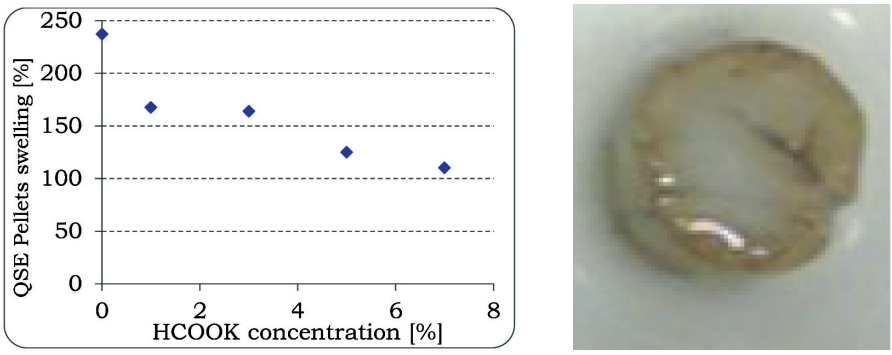


Fig. 5. QSE Pellets swelling under influence of mud with HCOOK addition (a), photography (b) – pellet condition for 7% of salt addition

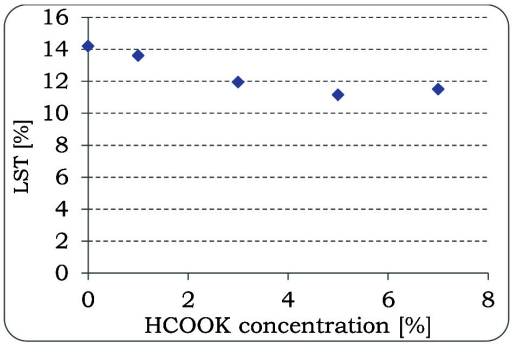


Fig. 6. Swelling (LST) of the Miocene shale under influence of mud with HCOOK addition

Based on undertaken tests, it was found that addition of potassium formate to the mud decreases QSE Pellets swelling. HCOOK in concentration of 1% limits swelling

from 237% to 167.38%. Further increase of its concentration effects in decrease of the swelling down to 110% at 7% concentration of HCOOK.

Linear swelling tests of the Miocene shale indicate that addition of potassium formate to the mud decreases sample swelling inconsiderably. At 5% concentration of potassium formate, it was noticed rock sample swelling value of 11%.

7. MUD-4 WITH $CaCl_2$ ADDITION

Last of the studied ionic inhibitors of hydration was calcium chloride. Test results are presented in Figures 7 and 8.

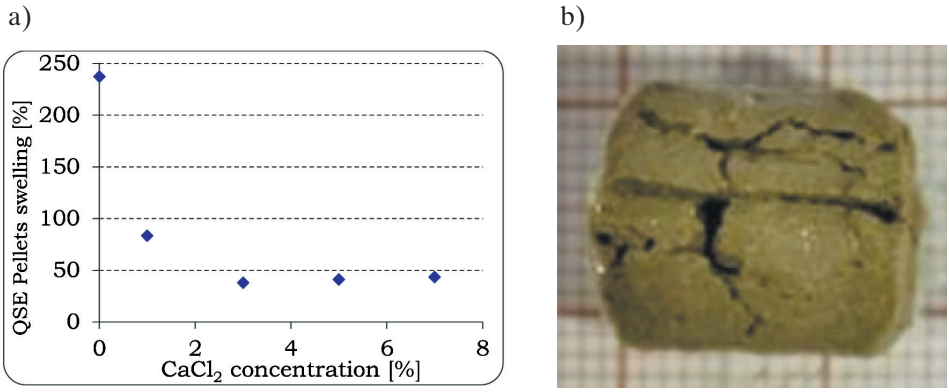


Fig. 7. QSE Pellets swelling under influence of mud with $CaCl_2$ addition (a), photography (b) – pellet condition for 7% of salt addition

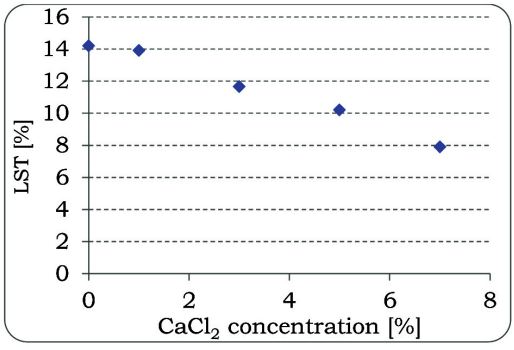


Fig. 8. Swelling (LST) of the Miocene shale under influence of mud with $CaCl_2$ addition

It was found that increase of the calcium chloride concentration in studied mud causes decrease of the QSE Pellets samples swelling and of the Miocene shale linear swelling. At 7% of salt addition, the value of linear swelling reaches only 7.9%, however pellets swelling decreases down to 43.2%.

8. TEST OF QSE PELLETS SWELLING – SUMMARY

Test results of QSE Pellets swelling under influence of the mud with addition of hydration inhibitors are presented in Figure 9 and in Table 2.

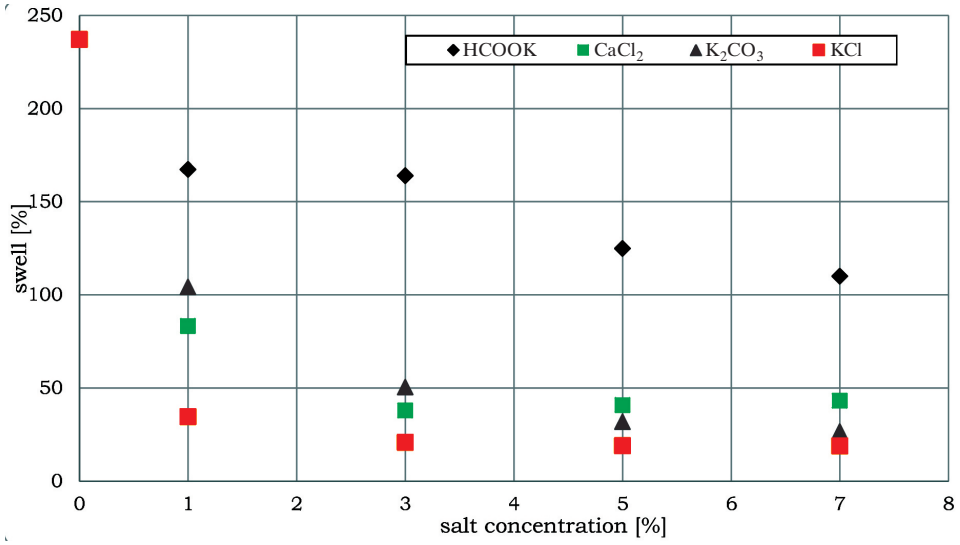


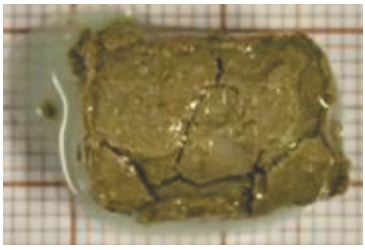
Fig. 9. QSE Pellets swelling under influence of muds with addition of ionic inhibitor

Table 2

QSE Pellets swelling under influence of mud with 3% of ionic inhibitor addition

Mud: ionic inhibitor	Result
Mud-1: KCl 3%	
Mud-2: K_2CO_3 3%	

Table 2 cont.

Mud: ionic inhibitor	Result
Mud-3: HCOOK 3%	
Mud-4: $CaCl_2$ 3%	

Based on the undertaken tests, it can be observed noteworthy influence of the ionic hydration inhibitors on QSE Pellets swelling. Potassium chloride limits samples swelling at the highest level, however concentration of the salt slightly impacts received results.

Application of potassium carbonate and calcium chloride effectively reduces swelling of the pellets at upper concentrations of the inhibitor. It also has been found that application of potassium formate in the studied mud limits swelling of clay pellets at the lowest level.

9. TEST OF MIOCENE SHALE SWELLING – SUMMARY

Test outcomes of linear swelling (LST) of the Miocene shale samples under influence of muds with ionic inhibitors addition are presented in Figure 10.

Conducted tests of linear swelling (LST) showed that inhibitor added to the mud in low concentration, just slightly decreases swelling of the Miocene shale samples. The greatest noticeable difference is observed for 7% concentration of the inhibitor. In that case, the most effective hydration inhibitor is calcium chloride. On the other hand, the lowest limitation of clay rock swelling has been noticed under influence of mud with addition of potassium chloride and potassium formate.

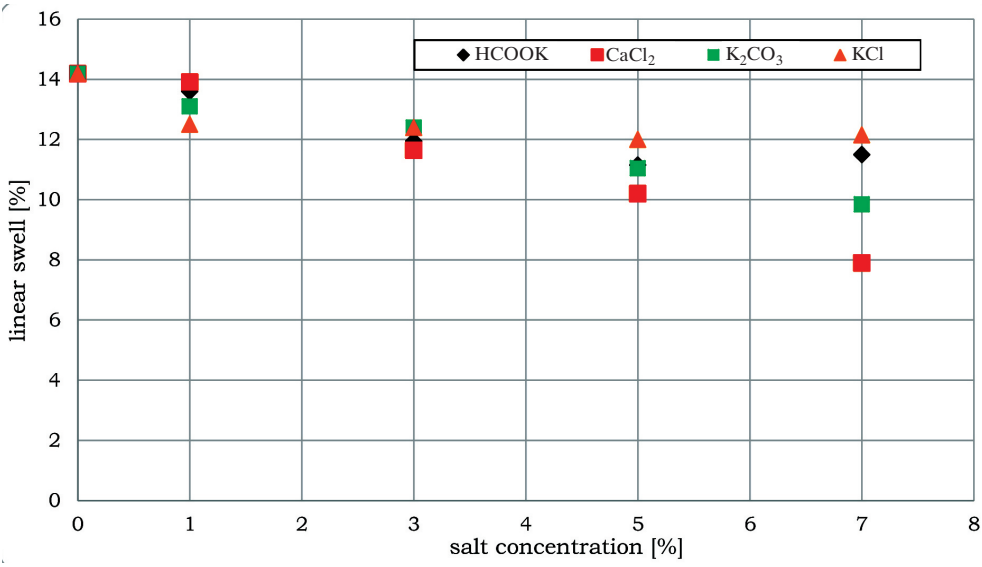


Fig. 10. Linear swelling (LST) of the Miocene shale under influence of muds with addition of ionic inhibitor

10. CONCLUSIONS

Undertaken studies showed that the muds with triple inhibition system, in which potassium chloride, potassium carbonate or calcium chloride was applied, limit clay samples (QSE Pellets) swelling successfully yet at a comparable level. Mud with an addition of potassium formate exhibits lowest inhibitive properties of clay samples swelling.

Based on the linear swelling tests, it was concluded that low concentration of the studied ionic inhibitors similarly limits swelling of the Miocene shale samples. Significant discrepancy is observed as the concentration of inhibitor grows up to 7%. In that case, the lowest swelling value was noticed for samples conditioned in the mud with addition of calcium chloride.

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[4] API Specification 13B-2, 5th edition, April 2014.