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THE APPLICATION OF METHYL GLUCOSIDE AS SHALE INHIBITOR IN SODIUM CHLORIDE MUD

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Abstract. The methyl glucoside drilling fluid, or designated as the MEG, is a recently developed environmentally-friendly water-based mud. It is said to possess performance that approaches the oil-based mud. This project studied on the effects of introducing MEG into sodium chloride (MEG/NaCl) mud in controlling shale hydration and dispersion at different concentrations, namely 5% to 35% by weight, through hot rolling dispersion test, based on the *American Petroleum Institute – Recommended Practice – 13I*. The inhibitive features were further evaluated against several shale samples which had different reactivity and clay contents. Besides, the performance of MEG/NaCl mud was also evaluated through series of rheological properties, fluid loss, mud water activity, and ageing process tests as recommended in *the American Petroleum Institute – Recommended Practice – 13B*. The experimental results revealed that MEG/NaCl mud system could satisfactorily exhibit shale stabilization performance. The effective concentration of MEG, however, was corresponding on the reactivity and clay content present in the shale. The experiment results also showed that MEG is a good fluid loss control agent.

Keywords: Hot rolling dispersion test; methyl glucoside (MEG); shale dispersion; shale swelling; water-based mud

Abstrak. Lumpur metil glukosida, atau dikenali sebagai MEG, ialah lumpur dasar air terkini yang mesra alam. Lumpur ini mempunyai prestasi yang hampir menyamai lumpur dasar minyak. Projek ini dilaksanakan bagi mengkaji kesan penambahan MEG ke dalam lumpur natrium klorida (MEG/NaCl) untuk mengawal pengembangan dan penyerakan syal pada beberapa kepekatan yang berlainan, iaitu 5% hingga 35% berdasarkan berat. Kajian ini melibatkan ujian penyerakan putaran panas yang berdasarkan *American Petroleum Institute – Recommended Practice – 13I*. Sifat pengawalan sedemikian turut dikaji menggunakan beberapa sampel syal yang mempunyai kereaktifan dan kandungan lempung yang berlainan. Selain itu, prestasi lumpur MEG/NaCl turut dikaji menerusi ujian sifat reologi, kawalan kehilangan turasan, aktiviti air dalam lumpur, dan proses penuaan, sebagaimana yang dicadangkan dalam *American Petroleum Institute – Recommended Practice – 13B*. Kajian menunjukkan bahawa lumpur MEG/NaCl boleh mengurangkan masalah pengembangan dan penyerakan syal. Namun begitu, kepekatan yang berkesan adalah bergantung kepada kereaktifan dan kandungan lempung yang wujud dalam sampel syal. Hasil kajian juga menunjukkan bahawa MEG ialah agen kawalan kehilangan bendalir yang baik.

Kata kunci: Ujian penyerakan putarasan panas; metil glukosida (MEG); penyerakan syal; pengembangan syal; lumpur dasar air

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1.0 INTRODUCTION

Borehole stability when drilling through water sensitive zone, especially shale formation, is one of the main problems in oil and gas industry with lost-time and trouble costs conservatively estimated at US$500 million/year [1]. The problems include sloughing shale, tight hole, gradual hole enlargement, poor hole cleaning, high torque, and cementing failures are the results of shale swelling and dispersion.

Over the years, oil-based mud (OBM) provides a definite solution to avoid borehole instability when drilling through water-sensitive shale. The use of OBM, however, has become more restricted by the environmental regulations. Therefore, much progress has been taken to look for inhibitive water-based mud (WBM) systems, these include the use of calcium treated mud, such as lime and gypsum muds. These muds contain relatively high concentrations of inorganic salts, such as sodium chloride (NaCl), potassium chloride (KCl), and calcium chloride ($CaCl_2$), modified asphalts and gilsonites. A variety of polymeric additives, namely the functionally anionic PACs and PHPAs, functionally cationic polymers (which exhibit both anionic and cationic characteristics) such as polyamino acids, and nonionic polymers the likes of polyols, glcerols, glucosides, polyvinyl alcohols (PVA), and HECs, are used to improve the rheological properties of those muds [2].

The methyl glucoside (MEG) drilling fluid is a recently developed environmentally acceptable WBM. Many researchers claimed that the MEG drilling fluid possesses the desirable characteristic of OBM [3 – 6]. They also highlighted that the use MEG drilling fluid can reduce or eliminate costly disposal of oil contaminated drill cuttings, minimize health and safety concerns, and minimize environmental effects.

In this project, a laboratory test was carried out to study the effect of MEG in sodium chloride (NaCl) mud in preventing shale hydration and dispersion through hot rolling dispersion test, based on the *American Petroleum Institute – Recommended Practice – 13I* [7]. The inhibitive features were further evaluated against several shale samples which had different reactivity and clay contents. Besides, the performance of MEG/NaCl mud was also evaluated through series of rheological properties, fluid loss, mud water activity, and ageing process tests as recommended in the *American Petroleum Institute – Recommended Practice – 13B* [8].

1.1 Methyl Glucoside (MEG)

Methyl glucoside (MEG) is a chemical derivative of glucose. There are several synonyms which are frequently used in representing MEG in chemical industry, these include methyl-d-glucopyranoside, methyl-d-glucoside, methyl-glucopyranoside, and methyl d-glucose ether. MEG is a compound used primarily in the manufacture of resins and coating, and has been utilized in personal care products, skin creams, lotions, and other cosmetics. The product that is currently available in commercial quantities is manufactured from corn starch [3].

Figure 1 shows MEG has a two-tiered cyclic structure containing four hydroxyl groups and one methyl unit. The molecule of MEG can exist in the different isomers [4]. Being a chemically modified sugar, the presence of methyl unit imparts several desirable characteristics, such as temperature stability, lower viscosity, and bacterial resistance [5]. Through the thermographic analysis, in Walker's research of MEG drilling fluid has showed that MEG molecules possess stability to about 177°C (350°F) before serious decomposition takes place in a nitrogen atmosphere for a 70% wt solution. Besides, a 62.5% wt solution of MEG remained fluid at –30°C (–22 °F). Extend from the test, a 40% of MEG allowed no growth of microorganism, even when inoculated with bacteria, mold, or yeast. MEG can be described as non-toxic and readily biodegrable. Therefore, it is suitable for onshore or offshore disposal [3].

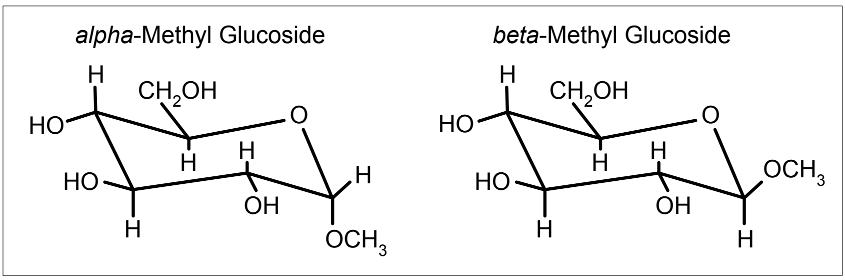

Figure 1 Methyl glucoside structure [3]

1.2 Mechanism of Shale Stabilization of MEG

The presence of high concentration MEG in water-based mud (WBM) is one of the most effective solutes which are able to demonstrate the desirable characteristics to form lower water activity (or high concentration) in the mud system with high membrane efficiency. Once the mud water activity is lower than shale, this could reduce the tendency of water to be absorbed by shale and thus preventing shale hydration and dispersion problems (Figure 2). As suggested by Headley, Walker, and Jenkins, this shale stabilizing mechanism is the same with OBM [5].

The reason for the MEG filtrate minimizing the damage is directly associated with its molecular structure. The presence of the hydroxyl groups in the MEG configuration may account for the unique ability to form a semipermeable membrane just inside the surface of shale. The hydrated MEG monomer seems to be the right size to penetrate the exposed pore spaces where the hydroxyls adsorb on the clay surfaces (perhaps by hydrogen bonding) [6]. In the process of adsorption, water is displaced from the surface and ordered structures of MEG are formed, while the water solvent remains free to move.

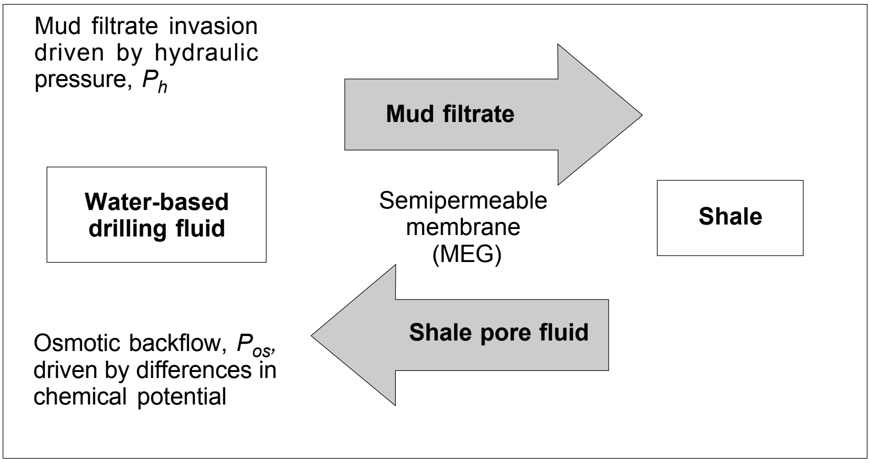

Figure 2 Principle of compensating hydraulic invasion of drilling fluid filtrate by osmotic flow in a non-ideal shale-fluid membrane system

In contrast, commonly used WBM, that uses inorganic salts (KCl or NaCl) to obtain low aqueous activity, does not establish an efficient semipermeable membrane because not only water but also dissolved salts ions can enter the shale to a limited extent. With little separation of solvent and solute, little osmotic force is developed either to augment or offset the hydraulic potential, tending to hydrate and weaken the shale [9].

2.0 MATERIALS AND EXPERIMENTAL SYSTEM

The laboratory work was accomplished at the Drilling Engineering Laboratory, Faculty of Chemical and Natural Resources Engineering, Universiti Teknologi Malaysia, Skudai. The discussion of the laboratory work was divided into two subsections, namely materials and experimental method.

2.1 Materials

The main materials involved in this laboratory work were the MEG mud and shale samples which were sourced from three different locations in Pahang.

2.1.1 Shale Samples Preparation

A shale sampling trip had been carried out in Pahang as the quality of shale was said to be comparable to those found in the vicinity of an oilwell. In fact, the study would give better results representation if the shale (in the form of cuttings) was sourced from an oilwell which was in the drilling phase. However, due to complex procedures of getting the shale from the oil companies and time factor, the only alternative that we had was to source from outcrop.

Three distinct types of shale sample had been collected. They were labeled and described as in Table 1. Each shale sample was ground into various smaller portions and dried in an oven at 105°C (221°F) overnight to get rid of all its water. Next, these samples were sent for X-ray diffraction (XRD) test to determine the shale mineralogy and to semi-quantify the minerals present. A Methylene Blue test was also conducted on these shale samples to identify their cation exchange capacity (CEC) values.

Table 1 Shale samples and description

Shale sample	Location	Physical description
A	Kuala Rompin, Pahang	Tan in color, obvious layering
B	Kuala Rompin, Pahang	Light grey
C	Muadzam Shah, Pahang	Mixture of dark grey and tan colors

Note: Tan is similar to reddish brown

2.1.2 Methyl Glucoside (MEG) Mud Formulation

Table 2 describes the 25% wt MEG/NaCl mud formulation (as an example) used in the laboratory.

Table 2 Lab formulation of 25% wt MEG/NaCl mud [5]

	Lab formulation	Function
Water	242.2 ml	As continuity phase
Methyl glucoside (MEG)	88.25 g	Primary inhibitive agent
Xanthan gum	1.5 g	Viscosifier
Potato starch	3.0 g	Fluid loss control agent
NaCl	22.5 g	Secondary inhibitive agent
Barite	90 g	Weighting material

2.2 Experimental Method

It was started by obtaining shale samples as mentioned in Subsection 2.1.1. The shale samples were then ground into smaller pieces and dried in the oven to remove all their water. The dried shale samples were then sent for mineral identification and sensitivity tests.

Mud samples were prepared as per the field formulation. The mixture of mud sample and shale was tested for its rheological properties and fluid loss. Those tests were conducted before and after the hot rolling processes.

The workflow of the experiment is shown in Figure 3.

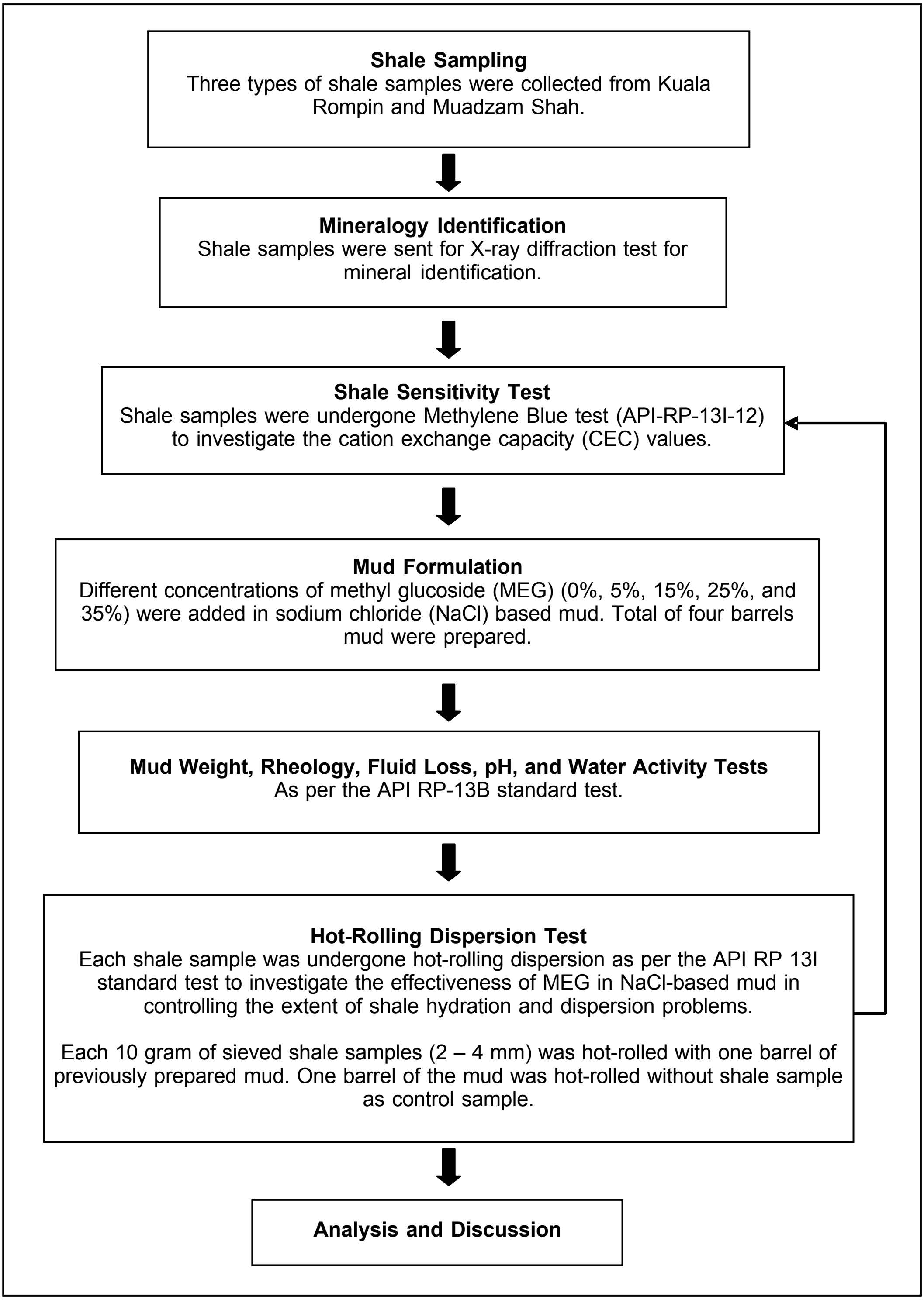

Figure 3 Summary of methodology

3.0 RESULTS AND DISCUSSION

The experimental results were discussed under four subsections, namely shale reactivity, hot rolling dispersion test, water activity, and fluid loss.

3.1 Shale Reactivity

As highlighted in Subsection 2.1.1, an X-ray diffraction (XRD) test had been conducted on those shale samples to determine the shale mineralogy and to semi-quantify the minerals present. Also conducted was the Methylene Blue test in order to identify their cation exchange capacity (CEC) values. The results are shown in Tables 3 and 4, respectively.

Table 3 Summary of shale sample mineralogy and their semi-quantitative amount

	Shale sample A	**Shale sample B**	**Shale sample C**
Quartz	▲▲▲▲▲	▲▲▲▲▲	▲▲▲
Hematite	-	-	▲▲
Trace	▲	▲	▲
Clay minerals:			
Illite	▲▲	▲	▲▲▲
Kaolinite	▲	-	▲▲
Montmorillonite	-	-	▲▲

Note: ▲▲▲▲▲ (Dominant), ▲▲▲ (Major), ▲ (Minor)

Table 4 Cation exchange capacity (CEC) value of available shale samples

Shale sample	**A**	**B**	**C**
CEC Value (meq/100 gram)	10	8	20

Shale reactivity is a function of types and amount of clay minerals present in the system. As suggested by Lummus and Azar (1986), the combination of X-ray diffraction analysis and CEC values can provide important information in the classification of shales sensitivity [10]. The ranking of these shales, in order of their decreasing water sensitivity, is C, A, and B.

3.2 Hot Rolling Dispersion Test

The inhibitive qualities of different concentrations of MEG in NaCl mud were evaluated by carrying out hot-rolling dispersion tests with different shale samples. 10.0 gram of sized shale samples (2.0 – 4.0 mm) was hot rolled with a formulated mud at 65.5°C (150°F) for 16 hours, after which the samples were recovered on a

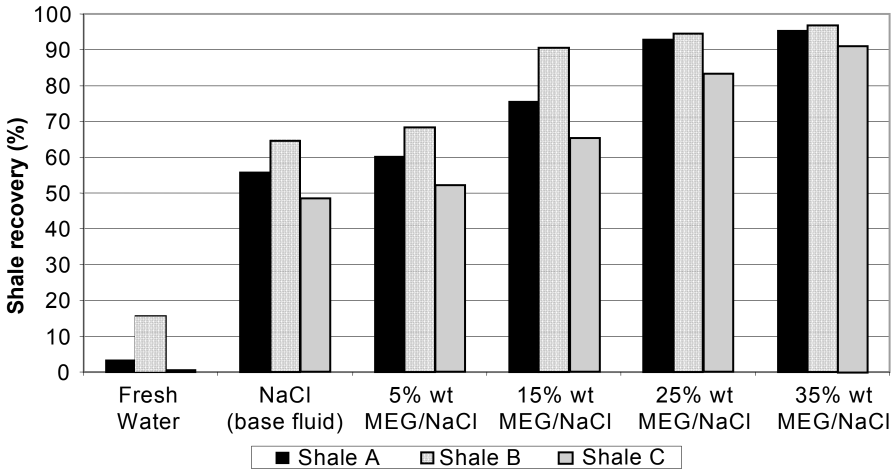

Figure 4 Hot rolling dispersion test, at 65.5°C (150°F) for 16 hours

1.0 mm screen and dried to a constant weight. Figure 4 showed the result of shale recovery (%) after the hot rolling dispersion test for three distinct shale types at different MEG concentrations.

The shale samples were initially hot-rolled with fresh water to determine their water-sensitivity. In water solution, the shale samples dispersed almost completely after 16 hours at 65.5°C (150°F), as shown in the first column of Figure 4. This indicated that the shale samples were readily dispersible because of the presence of illite, kaolinite, and montmorillonite minerals as detected from X-ray diffraction analysis.

9% NaCl mud was used as the base mud in this study. The NaCl mud is a commonly used shale inhibitive mud in the industry. After the hot rolling dispersion test, it was noticed that NaCl mud was capable in recovering in the range of 48 – 64% of each shale sample.

The third column of Figure 4 illustrates the inhibitive performance of combination 5% wt MEG with NaCl mud. Shale recovery was found between 52 – 68%. It was noticed that, 5% (wt) MEG did not show significant increment of shale recovery as compared to the base fluid. In other words, low concentration of MEG in a NaCl mud system did not contribute much in improving the inhibitive characteristics.

15% wt MEG/NaCl showed considerable increment of shale recovery as compared to the base mud. Shale recovery was found in the range of 65 – 90%. 15% wt MEG exhibited superior inhibitive performance with shale sample B, with about 90.6% shale recovery after hot rolled, which indicated that at this concentration, it was sufficient to inhibit shale hydration for less water-sensitive shale. 15% wt MEG, however, showed moderate inhibitive performance with samples A and C, which were more water-sensitive. This was a good example, showing that the inhibitive quality of MEG mud was also closely related to the sensitivity of the shale.

The last two columns of Figure 4 show the hot rolling dispersion results of 25% and 35% wt of MEG/NaCl, respectively. 25% and 35% wt MEG were found working satisfactorily with NaCl mud, exhibiting great shale inhibitive performance with every shale sample. This could be explained by the high shale recovery values, which are about 83 – 97%. The latter concentration of MEG performed better than the former, yet the results did not show very significant differences.

Generally, Figure 4 shows an upward trend that, with increased concentration of MEG in NaCl mud, greater shale recovery could be obtained, or contributing in controlling the extent of shale inhibition and dispersion. MEG/NaCl mud system gave commended performance in controlling shale hydration regardless of the presence of water sensitive clays, such as illite, kaolinite, and montmorillonite. The trend, however, becomes insignificant when the concentration was considerately optimal.

3.3 Water Activity

Headley, Walker, and Jenkins suggested that methyl glucoside (MEG) could help in shale stabilization using similar mechanism as the oil-based mud (OBM), which reduces the mud water activity and establishes efficient semipermeable membrane [5]. With this, an osmotic force can be developed between the drilling mud and shale system to offset the hydraulic hydration potential. This water transition will be eliminated when the activity of the drilling fluid equal or lower than the shale.

The measurement of water activity of the drilling muds, therefore, could be the best indicator explaining how MEG works satisfactorily with NaCl mud in controlling the shale hydration and dispersion problems. Aqueous activity of the muds was measured with an electro-hydrogronometer following American Petroleum Institute, RP-13B-2 [8].

Figure 5 illustrates the value of water activity for the formulated drilling muds. It is obvious that there was a downward trend of water activity against the increase of MEG concentration, for the control samples, both before and after hot rolling (BHR and AHR). In other words, increased concentration of MEG can reduce water activity.

Furthermore, when correlated with the result from hot rolling dispersion test, one could observe that, with lower water activity of a MEG mud system, the greater amount of shale recovery could be obtained (Figure 6). Noted also, when the shale recovery was considerately optimal, lower water activity was no longer contribute to greater recovery.

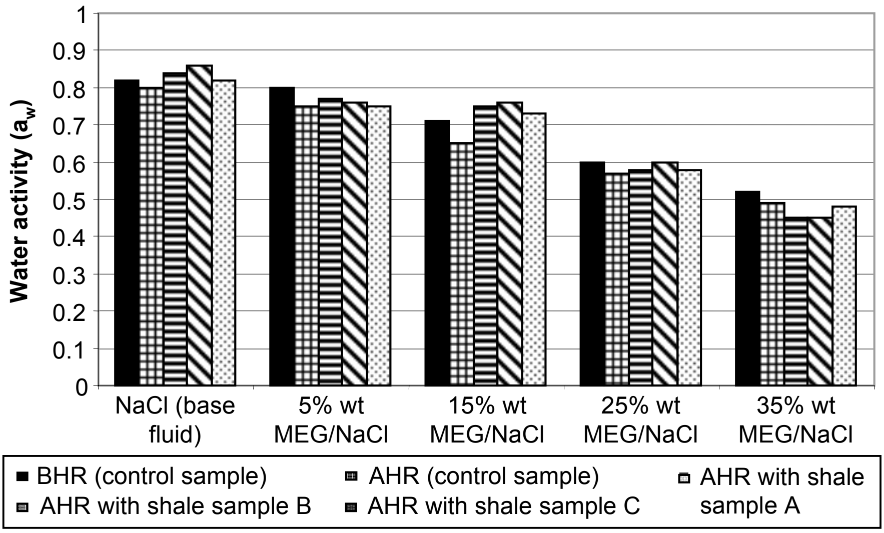

Figure 5 Water activity of various drilling fluids

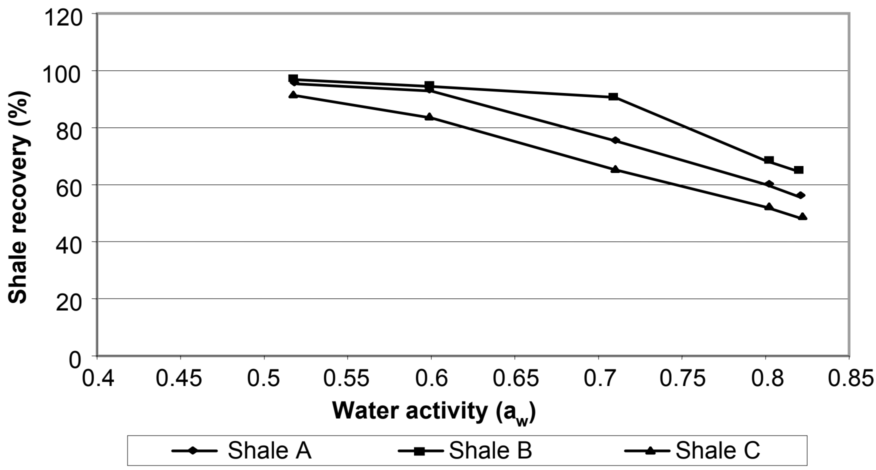

Figure 6 Correlation of shale recovery against initial water activity

3.4 Fluid Loss

The experimental results revealed that apart from giving positive performance in shale inhibition, MEG mud was also found to produce excellent performance in fluid loss control and low permeable mud cake. This can be seen in Figures 7 to 8.

Figure 7 shows the total fluid loss of 30 minutes against the various concentration of MEG/NaCl BHR and AHR. Fluid loss was found decreasing with increased concentration of MEG. The mud cakes formed were overall found to be thin, in the

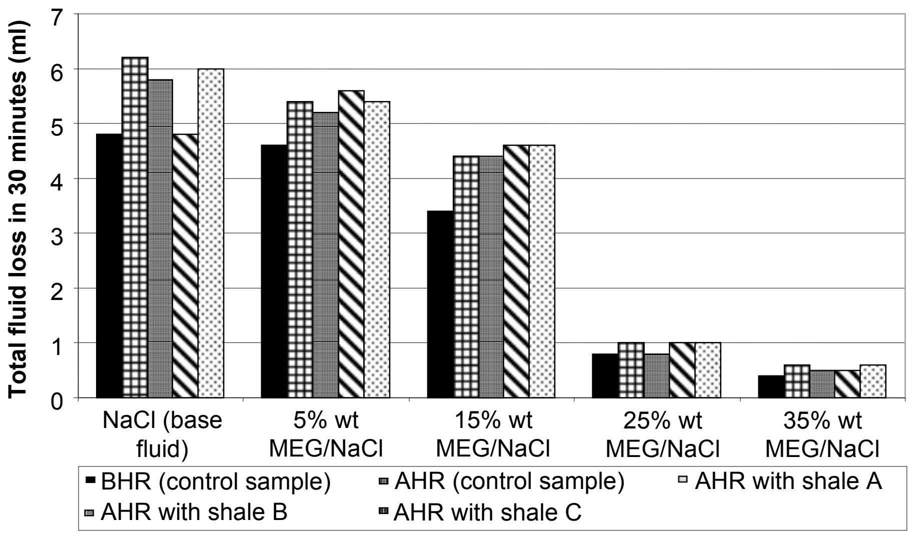

Figure 7 Total 30 min fluid losses of narious drilling muds

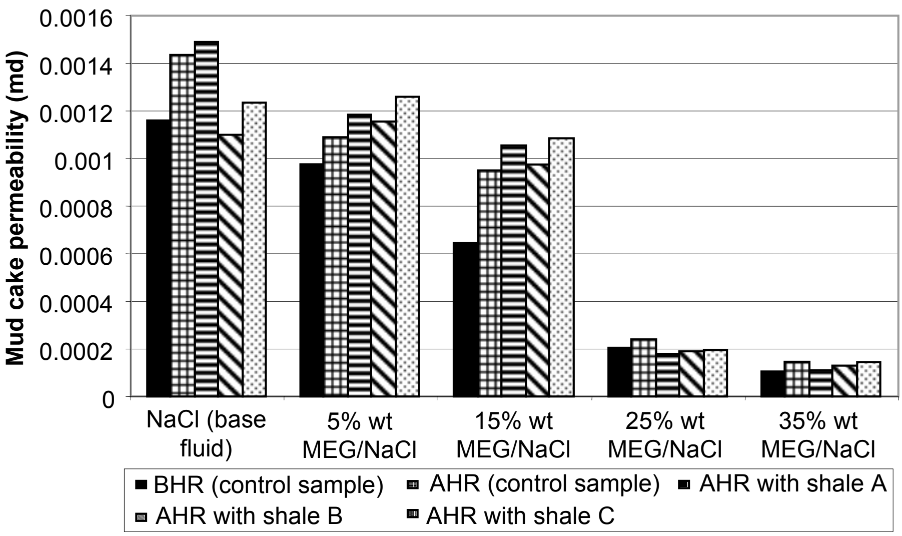

Figure 8 Mud cake permeability of various drilling muds

range of 0.9 – 1.3 mm. Figure 8 shows the mud cake permeability of various prepared drilling muds. The mud cake permeability was found decreasing with increased concentration of MEG, for both BHR and AHR cases. Mud cake permeability was calculated from the API filter loss and mud cake thickness using Darcy flow equation [11]:

$$k_{mud\ cake} = \left(\frac{V_f \mu h}{2tAP} \right)$$

This result was in good agreement with the result achieved by Zhang, Chen, and Yan [6]. They found that high concentration of MEG can control the filtration properties effectively due to the presence of hydroxyl groups in MEG, which capable of forming a tight mud cake. This could be attributed to the strong linkage between cyclic structures of MEG due to the hydrogen-bond attraction between molecules within the mud cake. This phenomenon enables MEG to form a tight mud cake, which has a low permeability. Therefore, total filtration loss can be reduced.

4.0 CONCLUSIONS

Based on the results and analyses obtained from this study, such as hot rolling dispersion, rheological properties, filtrate loss, water activity, and ageing process tests on the various prepared muds, there were several conclusions that can be drawn out:

(1) This study has suggested that addition of MEG can improve the inhibitive characteristics of NaCl-based mud in controlling the extent of shale hydration and dispersion. Generally, with increased concentration of MEG in NaCl mud, greater shale recovery can be obtained until the recovery was found optimal. As low as 15% wt MEG can sufficiently exhibit shale stabilization performance. Lower concentration of MEG (5% wt), however, did not contribute much in improving the inhibitive performance.

(2) Besides the concentration, the inhibitive quality of MEG/NaCl mud system was also closely related to the sensitivity and clay content of the shale. For instance, 15% wt MEG/NaCl showed superior inhibitive performance with low reactivity shale, but performed moderately with highly reactive shale. High concentration of MEG/NaCl (25% and 35% wt) mud system basically performed well in all shale samples regardless of the presence of water sensitive clays, such as illite, kaolinite, and montmorillonite.

(3) Greater concentration of MEG could further reduce the water activity of the NaCl mud system. Eventually, with lower mud aqueous activity, it was believed that this could reduce the tendency of water to be absorbed by shale and further preventing shale hydration and dispersion problems.

(4) It was also found that MEG is a good fluid loss control agent. Increased concentration of MEG could in essence decrease total fluid loss. Meanwhile, greater concentration of MEG could also further reduce the permeability of the mud cake.

NOMENCLATURE

API-RP	:	American Petroleum Institute – Recommended Practice
CEC	:	Cation exchange capaxity

GS	:	Gel strength, lb/100 sq ft
MEG	:	Methyl glucoside
NaCl	:	Sodium chloride
OBM	:	Oil-based mud
PV	:	Plastic viscosity, lb/100 sq ft
SBM	:	Synthesis-based mud
WBM	:	Water-based mud
XRD	:	X-Ray diffraction
YP	:	Yield point, lb/100 sq ft
A	:	Area of the filter cake, cm^2
a_w	:	Water activity
h	:	Mud cake thickness, cm
$k_{mud\ cake}$	:	Mud cake permeability, Darcy
P	:	Differential pressure, atm
V_f	:	Total volume of filtrate within t (sec) duration, cm^3
μ	:	Viscosity of filtrate, cp

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