The swelling effect of sodium-bentonite as an additive in water-based drilling sludge with different concentration of polyamine inhibition

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Abstract. A highly reactive sludge on drilling progress has become a common problem. The problem will cause swelling clay or high filtration loss. With a risk of swelling appearance and too much filtration loss that may cause, sodium-bentonite is widely used in drilling sludge to give more viscosity and optimal ability to hold and lift the cutting inside the borehole. It contains mostly montmorillonite like particles of sodium that overpower the iolite content inside it. Polyamine as an inhibitor to the clay can infiltrate into the bentonite c-spacing, which is a gap between two layers of bentonite structure. A test has been conducted to measure the effect of polyamine inhibition inside a water-base sludge formulation x that is previously inhibited with sodium-bentonite. These tests were conducted using a number of instruments such as API Filtrate loss, swell meter test, retort oven, and Vann vg meter with API Standard procedure. The result provides a distinctive conclusion about how the rheological elements react toward the polyamine existence with different concentrations (4gr-10,5gr) inside the sludge. This research also reveals that the sludge durability is different between room temperature and high temperature (300°F).

1. Introduction

A French sludge engineer named Pierre Pascal Fauvelle in year 1845, conducted drilling sludge to support drilling operation for the first time, with a main goal to hold and lift the cutting inside the wellbore [1]. Until now, drilling sludge is mandatory for every oil and gas drilling operation [2]. Hydraulic pressure from the drilling sludge can help withstand the formation pressure, because the condition of the hydraulic pressure and the formation pressure has to be slightly equal to minimize excessive filtrate loss and swelling clay [3]. Research has proved that OBM is able to maintain zero swelling clay, and minimizes filtration loss [4]. However, the usage of OBM is still quite risky as they are uneasy to mix, possesses high risk of circulation loss, less environmentally acceptable because of the toxic waste that leads toward health issues and environmental destruction, and also contributes high cost formation on drilling operation [5].

This research are focusing on the effectiveness of polyamine X (PAX) inside a inhibited-water base mud A(PMA). The primary data collected from PMA with an addition of PAX 1%-4% are API Fluid loss, percentage of swelling expansion from Linear Swell Meter, And also both of the effectiveness percentage. The result of this experiment gives a decreasing but fluctuative based by the fluid loss and shale expansion graphics because. A research in Bohay Bay China, reported a success to inhibit a polyamine in WBM drilling sludge to prevent swelling and excessive fluid loss [6]. The rheological parameter also proves quite an astonishing report, and concluded that polyamine is indeed effective [6].
2. Methodology
A well called Xingang-1 located in Bohay Bay, on the eastern coast of China, have successfully inhibited polyamine into its High Pressure Drilling Sludge (HPDS), and produced a stunning result that is way more powerful than any other type of WBM. The result shows that the utilized additive has become the closest one to reach OBM replacement target and have achieved zero swelling clay. Their test on bentonite inhibition, dispersion, bulk hardness XRD analysis, have proven that polyamine is significantly produce a better result than any other type of water based sludge inhibitor and produce a slightly better result than the OBM [6].

2.1. Sodium-Bentonite caused of swelling
Sodium-Bentonite is commonly used as a formulation material for drilling sludge. It used as a viscosifier to raise the viscosity of the sludge. Bentonite is valued as a high yield compound in the addition [7]. Because of that, bentonite possesses an ability to maintain a stable wellbore. Bentonite majorly contains 85% of montmorillonite rocks, which are highly hydrophilic [8]. Bentonite consists of smectite rocks that form flaky crystal shaped compounds. One of bentonite clay uniqueness is the thixotropic ability that allows it to turn into gel in static condition and able to liquefy and recirculate when involved in rotation or in a dynamic condition [2]. Sodium-bentonite possesses a Cation Exchange Capacity (CEC) of 94.36(meq/100gr), which makes it possesses a large adsorption ability which is the reason why it is highly reactive [7].

![Figure 1. Illustration of smectite / bentonite rock](image)

2.2. Type of swelling clay
There are two types of swelling clay, which are surface hydration swelling and osmotic swelling [7]. Surface hydration swelling usually happens inside the shale formation that contains montmorillonite clay, which could be caused by the drilling sludge or naturally contained inside the shale pore [10]. On the other hand, osmotic swell usually produced inside the drilling sludge, which is caused by a higher water cation concentration around it and water cation that is adsorbed by the c-spacing inside the interlayer of the bentonite [11].

2.3. Polyamine inhibition
To solve the absorption problem, an addition of an organic compound is required to change the bentonite’s property from hydrophilic to organophilic. This alteration will reduce the amount of fluid loss and swelling clay [12]. Polyamine is considered as an additive that is able to successfully reduce clay swelling and filtration loss [6]. Polyamine will infiltrate the c-spacing inside the interlayer of bentonite and plug the layers, connecting it into another layer of bentonite [13]. This additive, which is a water-soluble that contains amino group/natrium hydroxide, is able to flocculate by the existence of exchangeable atoms inside the bentonite and become soluble whether it was inside the shale formation.
or the sludge formulation [14]. Swelling clay and filtration loss will be reduced within the polyamine infiltration inside the bentonite clay. This will produce a better seal or plug on c-spacing and maintain fluid’s flow either from outside or inside the sludge [9]. However, researches on a suitable sodium bentonite and polyamine concentration and ratio are yet to be conducted.

2.4. Data source type
To sustain this research, there are two type of required data source, which are primary and secondary data. Primary data were obtained from drilling sludge laboratory research conducted by PPPTMGB "LEMIGAS". The data collected from sludge formulation test A with an addition of polyamine 1%-4% are API Fluid loss, percentage of swelling expansion from Linear Swell Meter, And also both of the effectiveness percentage. The test were conducted with the basic API standard procedure (API RB-13) [15].

Table 1. Drilling sludge formulation, a (PMA) created and formulated by PPPTMGB “LEMIGAS”.

| Product | SG | Dosage (gr) | Volume (ml) | Dosage (500 ml) | Volume (ml) | Time (minutes) | Speed |
|---------|----|-------------|-------------|----------------|-------------|---------------|-------|
| Aqua    | 1  | 294,09      | 294,09      | 420,13         | 420,13      | 10            | Low   |
| Bentonite| 2.5| 7,5         | 3,00        | 10,71          | 4,29        | 10            | Low   |
| KOH     | 2,13| 3,5       | 1,64        | 5,00           | 2,35        | 2             | Medium |
| Barite  | 4,25| 180       | 42,35       | 257,14         | 60,50       | 2             | Medium |
| Polyrex | 1,2 | 6          | 5,00        | 8,57           | 7,14        | 2             | Medium |
| PAC-L   | 1,55| 4         | 2,58        | 5,71           | 3,69        | 2             | Medium |
| XCD     | 1,5 | 2          | 1,33        | 2,86           | 1,90        | 2             | Medium |
|         |     | Mix it again (+10min) |         | 500,00         |             |               |       |

2.5. The laboratory apparatus
Laboratory apparatus required in this research includes sludge maker preparation equipment, and conditioning tester equipment adjusted to room temperature until 300°F. The instruments used in sludge maker preparation are: Hamilton sludge mixer, mixer Cup, Electrical weight scales, stopwatch, spatula, Aging Cell, Retort Oven, Fann VG Meter, API Filter press, Ofite Compactor, and Dynamic Swell meter.

2.6. Research procedure
This research is conducted with API 13B-1 standard procedure [15]. This research was conducted to acknowledge sludge rheology so that the created sludge formulation quality can be precisely produced. Once the formulation has been mixed, the sludge will be tested at 68-77 °f and 300°F. After that, the
sludge that was previously tested will be involved in API filtrate loss test and dynamic swell meter to test the clay’s expansion that swell on the surface of the shale. The experiment includes several tests. The polymer sludge formulation A (PMA) design passed the filtration loss and swelling clay/shale development test successfully. The main goal of this research is to acknowledge polyamine performance to inhibit shale development. The Test subjects are as follows:

- Formulation of basic polymer sludge A (PMA)
- PMA + polyamine X (PAX) 1% (4 gr)
- PMA + polyamine X (PAX) 2% (7 gr)
- PMA + polyamine X (PAX) 3% (10.5 gr)
- PMA + Polyamine X (PAX) 4% (14 gr)

The dynamic swell meter requires a shale sample. By utilizing the compactor, 10 gr of sodium-bentonite was printed and pressed with a 6000 psi pressure. The result will produce a tablet like shape, which will be used on shale sample. The shale then inserted into a cup and soaked with sludge that was designed in the previous 24 hours. A static state condition on room temperature was used. During the test, the shale’s occurrence is reflected in the form of expansion percentage.

3. Results and discussion

The first experiment conducted is a Fluid Loss by utilizing API Fluid Loss on PMA sludge. After conduction fluid loss test, the sludge was inserted into a dynamic swell meter. The 24 hours test shown that bentonite expansion reached 52% on polymer sludge formulation A (PMA) on a temperature of 77°F, and 60.5% on temperature of 300°F with original sodium-bentonite pallet weight of 10 grams.

![Figure 3](image-url)

**Figure 3.** This graphic is showing that pax 1%-4% inhibition is able to decrease fluid loss.

However, the Most Effective Result was Shown When PAX 2% was Added. Every Subject was Tested for 30 Minutes.

3.1. Result for polymer base sludge formulation A + polyamine X 1%-4%(4gr-14gr)

If compared to polymer sludge formulation A (PMA) without the addition of Polyamine X (PAX), the fluid loss and swell expansion values decrease after the polyamine X 1% (4gr) inhibition. This proves that polyamine is able to inhibit and reduce the swelling clay and fluid loss for sodium-bentonite clay [18]. If we look at figure 3, as 3% PAX was added, fluid loss rate was decreased if compared from 2% of PAX inhibition. The result of 3% PMA+PAX. If we compare the results, (as shown in Figure 4), the
1% PAX addition produce a higher result than 2% PAX addition. However, fluid loss on 3% and 4% PAX addition is slightly higher than 2% PAX Addition.

![% Shale Expansion](chart.png)

**Figure 4.** This graphic shows that 1%-4% PAX inhibition can inhibit swelling clay production in the shale.

However, Similar as figure 3, this graphic shows s2% PAX Addition on PMA is the most effective. every subject was tested for 24 hours.

**4. Conclusion**

Even though the amount is relatively small, polyamine X (PAX) additive addition with 1%-4% concentration on Polymer Sludge Formulation (PMA) is proven to be able to decrease fluid loss if compared with fluid loss on PMA. PAX with low concentration is proven quite effective to inhibit surface hydration swelling, but the dosage must be well managed so it would be suitable with sodium bentonite. This situation is created because polyamine and sodium-bentonite possesses high viscosity characteristics and highly fluctuating [9,7]. Through graphic expansion, polyamine inhibition can also change sodium-bentonite into organophilic. If we compare 3% and 4% PMA+PAX and 2% PMA+PAX a slight increase on swelling clay is detected. This situation is created because polyamine and sodium-bentonite ratio is too high, which create accumulation and fluctuation. Polyamine added polymer sludge also experience osmotic swell that can be seen through expansion increase in every polyamine addition due to sludge exposition against high pressurize during sludge filtrate test.

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