

Various Case Histories to Assess the Effects of Clotting and Hydrolysis on the Drilling Operations

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Abstract

The goal of this paper is to understand the challenges of facing the clotting and hydrolysis during the drilling operations. In addition, to understand the main reasons that are responsible to initiate these complex problems, and how to mitigate or avoid them in order to optimize the drilling process.

Two case histories of the clotting issue in the South Rumaila field will be reported and analyzed, and both of them occurred at that time in Well-306, the Shuaiba formation. The first one that was related to coagulation was experienced due to using over-concentrations of viscosifiers in preparing a treatment to stop the complete loss, the free water was not sufficient to hydrate these high concentrations of clays and polymers. The remedy was too viscous and could not be pumped from the mixing surface tank. The crew tried to utilize more water along with thinners additives to break the mud. After the failure to cure this issue, the crew decided to pour out. While the second case history of the flocculation problem was faced because of adding the dry chemical products too fast and directly through the mixing tank and not by the mud hopper. Thus, fish eyes were observed at that time in the mud, and the mud was very thick with difficulties in flowing. This issue was solved by dividing the mud volume into two surface mud tanks, then lignosulphonate and chrome-lignite were used to break the high gel strength. The executed action was successful to replace the mud flocculation by mud deflocculation.

The third case history will be elucidated in this work, which is related to facing the hydrolysis phenomenon. Hydrolysis was experienced while penetrating the anhydrite lithology in the Rus formation in Well-9, Nahr Umr field. Hydrolysis issue was faced due to low alkalinity ($\text{pH} < 6$), and a bacterial action took place in the drilling mud. The mud was almost dysfunctional and unable to implement the required duties. Hence, non-productive time and a high cost were introduced in this well due to the high contamination of calcium ions ($\text{Ca}^{++} > 1900 \text{ mg/l}$). The rig was shut down, new drilling fluid was prepared by using regular (soft) make-up water with sodium carbonate (Na_2CO_3) to make the mud resistant. The old mud was circulated out and replaced by the new one. The action was efficient to complete drilling the Rus formation without issues. While the last case history will be related to having hydrolysis due to drilling cement that was used to secure the surface hole in Well-12, Nahr Umr field. Extreme pH and high calcium content caused

to change the drilling fluid properties and experience a separation between the continuous phase and the desired solids. The mud was treated by sodium bicarbonate (NaHCO_3) to solve the mud hydrolysis, and it was an effective additive.

Introduction

The specifications of a drilling mud can be evaluated by its chemical and physical components. The considerable features of the mud should be tested and outlined twice daily in the drilling night and morning reports (Rabia, 2002; Basra Oil Company, 2007). Drilling fluids have many significant duties in continuing the drilling operations and ensuring reaching the target depth. Historically, the mud major purpose was to lift the cuttings from the bottom of the annulus to the rig surface. However, at the present, the drilling fluids have many targets embodying maintaining the walls from caving in (collapsing) and precluding oil and gas flowing into the wellbore (kick). In order to achieve the desired characteristics of the drilling fluids, a sophisticated fluid blend with a base fluid such as oil, freshwater, or saltwater with various substances and chemicals introduced to the mud based on a layout process. The design process of fluid is generated so that the mud obtains particular features (MI-Drilling fluids, 2000).

Introducing a very high concentration of additive, especially clays and polymers, the effect basically is the increase in the yield point, gel strength, and the plastic viscosity. In addition, it will reduce filtrate significantly. However, the other main concerns of having over-concentrations of viscosifiers are the free water reduction (continuous phase) and the negative effect on the mud's ability to flow. These concerns are defined as mud clotting problem. Clotting (flocculation) is a condition in which bentonite clays, polymers or other viscosifiers become highly attached and attracted to each other, which in turn will constitute a friable structure and creating large particles. While hydrolysis is defined as the chemical interaction between the liquid phase and the additives. Due to the extremely acidic environment or very high alkalinity, hydrolysis will be experienced, and the clays, polymers or other viscosity additives will separate from the base fluid, in return, these chemical additives will lose their potential to reduce filtrate or perform well in regards to the other drilling mud properties.

In addition, mud can experience mud flocculation issues if the dry products will be introduced quickly into the make-up water, particularly if the chemical additives will be directly added through the aperture of the mixing tank and not through the mud hopper. Thus, some products will not be fully hydrated, and fish eyes will be observed in the mud. The consequences of having clotting lead to maximizing gel strength, plastic viscosity, and yield point; however, the filtration may not be affected since the product already reach the saturation and no free continuous phase (Basra Oil Company, 2007).

Hydrolysis can usually happen if there is an extremely low pH (below 7), then hydrolysis will be experienced, and the polymers will separate from the liquid phase and lose its potential to reduce filtrate or perform well. Moreover, hydrolysis can be faced if a bacterial action takes place in the mud, which at the end will be the same phenomenon, a decrease in pH below 7. But a more extreme acidic environment for sure will cause hydrolysis. Lastly, an extreme base pH can lead to having a hydrolysis problem. A good example of an extreme pH is around 13 or above. That is why, contamination with the cement will lead to polymer degradation, and in the end cause an increase in filtration. Hydrolysis is more related to the effect of the liquid phase and the ability to hydrate, and solids will be separated from the water, but may not generate clots. Hydrolysis will maximize the filtrate and minimize the viscosity (Basra Oil Company, 2011).

This paper is a collection of four case histories and analyses of the accomplishment of the real remedies utilized to control the clotting and hydrolysis phenomena in the drilling fluids in South Rumaila and Nahr Umr fields. The executed treatments were precisely compiled from mud drilling reports and analyzed to better recognize these troubles. Analysis and comprehension of these case histories will give a beneficial reference for averting or at least minimizing clotting and hydrolysis concerns during drilling. These four complicated problems diagnosed and the required actions to treat them were selected. This work can serve as a practical strategy for avoiding or mitigating the clotting and hydrolysis for other oilfields.

Clotting Phenomenon in Drilling Mud (Two Case Histories in South Rumaila Field, Well-306, the Shuaiba Formation)

Located in Basra city, Southern Iraq, the Rumaila field is considered one of the most significant fields since it is a super-giant oil field and considered the third-largest field in the world. **Figure A.1 (Appendix A)** illustrates the location of the Rumaila field. Two case histories that are related to the coagulation issue in the drilling fluid will be clarified, and both of them have happened in the Shuaiba formation, South Rumaila field. This zone is approximately located at 2900 m in the production hole, and its lithology is limestone with little to no visible porosity. This formation is highly susceptible to having mud loss due to the induced fractures since it is very weak (Basra Oil Company, 2016).

Case 1: Mixing Excessive Viscosifying Additives to Stop Mud Loss in the Shuaiba Formation, Well-306, the South Rumaila Field

Lost circulation problem is largely expected to be occurred in the Shuaiba zone due to the induced fractures. Consequences such as non-productive time and cost will be faced due to the mud losses. In this case history, the Shuaiba formation was suffering from the complete loss, and many treatments were implemented to cease the losses but without any benefits. Hence, one of the crew members proposed to use a specific thick patch to remedy the complete loss. The high viscous patch was blended in the surface mixing tank with the additives shown in **Table A.1**. The size of the remedy was 10 m³ (Basra Oil Company, 2007).

Due to the high concentrations of viscosity elevators, the patch was very viscous and thick. At that time, even the mixer (agitator) was not able to move the mud easily due to the high viscosity and strength, and the pump could not pump it to the wellbore. Thus, the crew tried to use viscosity reducer such as water, lignosulphonate, and chrome-lignite to break the gel, but they were not successful to mitigate the viscosity. At that time, this treatment took around 4 hours to be prepared and more than 3 hours to fix it. The rig was shut down and all that was considered as non-productive time. Therefore, the company man decided to pour out the mud treatment and clean the mixing tank in order to prepare a new one. The main reason behind this extreme viscosity was introducing over-concentrations of chemical additive, which in turn led to having the mud clotting. In other words, the continuous liquid phase (10 m³) was not sufficient to provide homogenous mixtures and particle dispersion. Consequently, the solid particles got closer and attached to each other to make larger particles (Basra Oil Company, 2007).

Case 2: Bad and Fast Mixing of the Chemical Additives in the Shuaiba Formation, Well-306, the South Rumaila Field

This case history will be concentrated on the big and common mistake, which has usually been done by the technicians, and this mistake is related to the bad and quick mixing of the chemicals. In the night shift and during drilling the Shuaiba formation, the mud engineer asked one of the technician to mix new mud to substitute the mud loss in this formation, and to quickly maintain the wellbore mud pressure in order to avoid any consequences related to the kick (flow) from the abnormal zones, which are located above the Shuaiba formation. At that time, the technician misunderstood the mud engineer. Thus, the technician decided to add the required chemical additives to prepare the new mud through the mixing tank and not through the mud hopper in order to accelerate the process. Due to that action, fish eyes were recognized in the mixing tank, and that was a big indication to have the flocculation issue. Some of the dry products were not fully hydrated, then the plastic viscosity and yield point were maximized due to the clotting issue. The mud engineer

suggested to take some of the new mud to the reserve tank, then water and thinner materials were introduced to fix the viscous mud. The problem was solved, but non-productive time was around 5 hours, and the risk of having kick was high at any moment due to the pump off conditions and the mud level reduction in the wellbore. Thus, it is very crucial to mix the chemical additives using the hopper in order to provide sufficient time for interaction between the dry products and the liquid phase, and the mud will be more homogenous, then the mud deflocculation will replace the mud flocculation (Basra Oil Company, 2007).

Hydrolysis Phenomenon in Drilling Mud (Two Case Histories in Nahr Umr Field, Well-9 and Well-12)

The Nahr Umr field is a big field located in Southern Iraq. One of the time-consuming problems in the Nahr Umr field is calcium contamination due to penetrating the anhydrite and gypsum formations or penetrating cement. **Figure A.2** shows the location of the Nahr Umr field in Basra city. Two case histories that are associated with the hydrolysis in the drilling mud will be reported. The first one happened because of drilling the Rus formation in the Nahr Umr field. The Rus formation is an anhydrite formation with white, firm, moderately hard, no porosity, massive, occasionally soft, no oil show, with a thickness between 140–190 meters. The second case history related to penetrating the cement that was used to secure the surface casing (Basra Oil Company, 2011).

Case 3: Penetrating the Rus Formation, Well-9, Nahr Umr Field

Spud mud was utilized to drill the Rus formation without adding sodium carbonate as pre-treatment to precipitate the calcium content and maximize the alkalinity. The mud was not able to perform the required functions, especially lifting the cuttings outside the annulus to the surface. The cuttings were accumulated on the bit and caused high torque and drag issues. At that time, the crew thought that the high torque problem was due to the bit itself and not due to the mud. Thus, they decided to pull out the drill string and evaluate the bit. However, the mud engineer said that the high torque issue was because of the dysfunctional drilling fluid and not the drilling bit performance. The mud engineer said that mud lost its potential to provide an efficient transportation ratio due to the high calcium contamination, then cuttings settled and accumulated in the bottom, which in turn caused cutting bed issue. The mud was inefficient to do the desired duties due to the high contamination of calcium ions ($\text{Ca}^{++} > 1900 \text{ mg/l}$) and extremely low alkalinity ($\text{pH} < 6$). Therefore, hydrolysis was experienced. The separation between the solid particle and liquid phase was observed, then the viscosity, particularly the yield point was highly reduced. In addition, the initial and final gel strengths were slightly different as well as the filtration was maximized (Basra Oil Company, 2011).

The company man decided to trip out the drill string to the surface casing shoe and shut down the rig. New resistant mud

was made to replace the old mud. The old mud was saved in the reserve mud tanks. The new mud consisted of the chemical additives shown in **Table A.2**. The new drilling fluid was very successful to drill the Rus formation with high performance and without concerns about the calcium content since the calcium was precipitated by sodium carbonate and the pH was maintained (Basra Oil Company, 2011).

Case 4: Drilling Cement, Well-12, Nahr Umr Field

Penetrating the cement anywhere requires using drilling mud that is pre-treated by sodium bicarbonate in order to precipitate the high calcium content and minimize the alkalinity, which are associated with drilling the cement. In this case history, fresh-bentonite mud was utilized to drill the cement in the last three joints of the surface casing string. The mud was highly affected by the cement, and it was not effective to penetrate cement. Extreme alkalinity ($\text{pH}=14$) and high calcium content ($\text{Ca}^{++} > 2200 \text{ mg/l}$) caused to have hydrolysis, and the mud lost its capability to achieve the required functions. At that time, mud condition was prepared, and it was added to the dysfunctional mud to make it resistant to the cement drilling. The new mud was treated by sodium bicarbonate in order to precipitate the calcium and reduce pH. Then, the new mud was successful to treat the old mud and drilling the cement was completed without issues (Basra Oil Company, 2011).

Conclusion

Clotting and hydrolysis are very popular and troublesome issues during the drilling process, and all types of drilling fluids are susceptible to these problems due to using excessive chemical additive, fast mixing, high acidity, and extreme alkalinity. Thus, it is required to do pre-treatment by introducing the appropriate amount of chemical additives, mixing the chemical additive with the liquid phase slowly through the mud hopper, and making the mud to be resistant before drilling anhydrite and gypsum formations as well as cement. Based on this work, the following points were concluded:

- Summarizing case histories from drilling data with consolidated analysis will give a solid picture for how to deal with challenging issues. Thus, it is crucial to introduce more case histories to be evolved as workable and fundamental resources, which will benefit as reference substance for controlling clotting and hydrolysis problems at the well-site for drilling personnel.
- It is recommended to do a pilot test in the drilling laboratory to determine the required amount for each chemical additive before introducing them in the mud tanks system, to be as a proactive approach for avoiding the over concentrations.
- All chemical materials have to be added and mixed through the mud hopper to provide a good homogenous mixture between the continuous phase

and the additives. Thus, avoiding the coagulation issue.

- It is worthwhile to employ soft make-up water to blend fresh-water-based mud if applicable. If not, hard make-up water has to be pretreated with calcium carbonate before introducing the desired chemical additive. Ca^{++} has to be minimized in hard make-up water to 200 mg/l or less.
- It is practically applicable to add sodium carbonate prior to drilling anhydrite or gypsum formations to make the drilling mud more resistant to contamination and avoid extreme pH reduction. In the same context, sodium bicarbonate has to be added to the drilling mud before penetrating the cement in order to prevent having a very high pH and to ensure precipitating the calcium ions.

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Appendix A



Figure A.1. Rumaila Field (Parks, 2010)

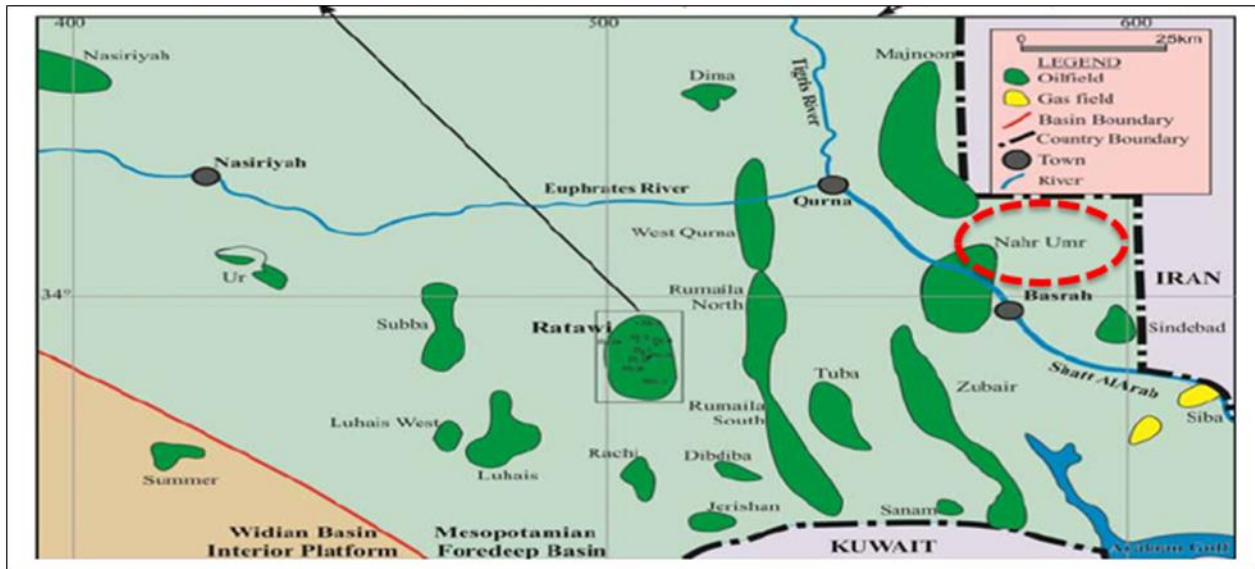


Figure A.2. Nahr Umr Field (Al-Khafaji et al., 2015)

Table A.1. The Blend of the Thick Patch Treatment (Basra Oil Company, 2007)

Additive	Amount
Regular Make-up Water	10 m ³
Caustic Soda (NaOH)	25 kg
Sodium Carbonate (Na ₂ CO ₃)	25 kg
Lime	100 kg
Bentonite	3000 kg
High Viscosity Polyanionic Cellulose (PAC-HV)	100 kg
Attapulgate	1200 kg
Xanthan Gum (XC Polymer)	100 kg

Table A.2. The Composition of the New drilling Fluid (Basra Oil Company, 2011)

Name of Material	Concentration	Purpose
Regular water (Ca ⁺⁺ < 50 mg/L)	90 m ³	The liquid phase (base-mud)
Caustic soda (NaOH)	1.5 kg/m ³	pH elevator
Sodium carbonate (Na ₂ CO ₃)	1.5 kg/m ³	For calcium precipitation
Bentonite	60 kg/m ³	Dispersed phase (viscosifiers)
Low Viscosity Carboxymethyl Cellulose (CMC-LV)	6 kg/m ³	Filtration control agent