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RESEARCH ARTICLE

EFFECT AND OPTIMIZATION OF BACTERICIDE TO CONTROL BIODEGRADATION IN NON DAMAGING DRILLING FLUID (NDDF)

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ABSTRACT

Non Damaging Drilling Fluid (NDDF) is a polymer mud system mostly used in the reservoir sections to avoid formation damage. Non degradable compositional fine solid e.g. Bentonite (clay) is not used in NDDF to decrease the reservoir damage and environmental pollution. It incorporates long-chain, high molecular weight polymers; some of which are viscosifiers and some are fluid loss control agents while others are multifunctional. All these polymers are very much vulnerable to bacterial attack or biodegradation by which the complex molecules are broken down by micro-organisms to produce simpler compounds. Due to this, the Bactericides are commonly used to kills the bacteria in the NDDF containing natural polymers. In this work, an attempt has been made to study the effect of varying composition of Bactericide/Biocide on the different properties of laboratory formulated NDDF and to choose its optimum composition for the oilfields of Upper Assam Basin based on the mud parameters generated in the laboratory and the required mud parameters in these oilfields. Thus, this paper reports the effect and optimum composition of Bactericide to control the biodegradation of the NDDF.

INTRODUCTION

The drilling fluid decreases well's productivity by rendering formation damage in numerous ways. These fluids are retained at higher pressure than the formation pressure to avoid the entry of formation fluid into the wellbore. Due to this overbalance pressure, the solids and filtrate enters the formation and thereby induce formation damage. The fine solids (drilling fluid's compositional solids, drilled cuttings and polymers' particles) may plug the pore throats to reduce formation permeability; and the filtrate may react with the formation minerals to mobilize and afterward re-deposit them, hydrate the clay minerals around the formation particles, and may generate scales due to the reaction between filtrate and formation fluid leading to a reducing rock permeability.

The conventional water-based mud may cause wellbore instability, formation damage, torque & drag, stuck pipe, logging and primary cementation failures, borehole washouts etc. in water sensitive clays and shale formations. These problems may become even more serious in directional or horizontal wells. The alternate option of oil-based mud is also economically and environmentally unfeasible (R.K. Dwivedi, 2010). Moreover, due to the current rigorous environmental rules and regulations, the oil industries are attracted to environmental friendly bio-degradable drilling fluids.

According to Nitya G. Mandal *et al* (2006), to counter the formation damage, an optimally designed drilling fluid should not use dispersant and non-degradable fine solids like- Clay, Barite, etc. in the mud; should reduce fluid loss; should minimize drilled fine solids in the mud; should produce inhibitive saline filtrate which would not swell the clay envelops in the formation particles and should not react with the formation fluid to generate insoluble precipitate; should contain specialized sized materials to bridge all exposed pore openings; should deposit a thin and tough non - damaging filter cake that can be easily and effectively removed by acid jobs; must hold all the relevant drilling fluid characteristics; should lower overall well costs and most importantly must optimize the production without neglecting HSE regulations.

Therefore, we must not use the non degradable Clay (Bentonite) as the rheology control agent in the drilling fluid used to drill the pay-zone section, although it used to gives excellent rheological properties. Once the formation is plugged by the clay particles, it is very difficult to remove the plugging in future. Accordingly, the Non Damaging Drilling Fluid (NDDF), a clay and barite free polymer mud system is revealed basically to use in the pay zone sections to avoid formation damage and to keep pay zone or reservoir intact. It incorporates long-chain, high molecular weight biodegradable polymers in the systems either to encapsulate drill solids to prevent

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dispersion or to coat the shales for inhibition as well as to increase viscosity and reduce fluid loss.

Studies conducted by L. Bailey *et al*. (1999) also revealed that solids invasion is one of the primary causes of formation damage from drilling fluids. Fine particles penetrate deeply and are not easily removed by back-flushing.

Moreover, it is important to diminish the exchange of fluids and solids between the well and the formation. And, accordingly we add particulate material in the drilling fluid so as to form a low permeable filter cake on the wellbore walls and thereby minimizing the invasion of filtrate and solids into the formation and subsequently, the cake must be removed to increase the flow area and minimize damage. The acid-soluble solids are generally added in NDDF in order to encourage pore plugging and minimize fluid penetration. Also, some specific polymers are added to reduce fluid invasion by sealing the walls of the borehole and to control the rheology due to its long chains of monosaccharaides.

The XC-Polymer, a biopolymer is used in NDDF instead of the non degradable Bentonite (clays) to provide rheology for good lifting capacity and ROP and to encapsulate drill solids to prevent dispersion. It is also a fluid loss reducer and coating agent for inhibition. XC-Polymer is a high molecular weight polysaccharide produced by fermentation of carbohydrate with Xanthomonas Campestris. It is a premium grade viscosifier and display exceptional shear thinning properties and good suspension characteristics even in the absence of inorganic colloids. This allows for high penetration rates, borehole cleaning and pays zone protection. There is an increase in the rheological properties of drilling fluid as XC-Polymer increased. The thickness, porosity and permeability of the filter cake of the drilling fluid also slight decreases as XC-Polymer concentration increases (Blkoor O. Shafeeg and K.A. Fattah, 2013). It is highly bio-degradable. Therefore, the XC-Polymer is used in NDDF as a substitute of the non degradable clays (e.g. Bentonite). XC-Polymer works excellently as the rheology control agent in NDDF which also has a moderate role in controlling the fluid loss of the mud. (Prasenjit and Subrata, 2015d)

Some clay specifically the montmorillonite a member of the smectite group absorb hydrogen ions into their structure when comes in contact with fresh water and causing swelling of the clay resulting in a reduction of the pore volume and possibly plug in the pore throats. Therefore the filtration loss should be as low as possible by forming high quality low permeable mud cake of as thin as possible. (Prasenjit and Subrata, 2015c) The Pre-Gelatinized Starch (PGS), an environment friendly non-ionic polysaccharides which control the Filtrate and Particle invasion, and Mud Cake thickness by increasing the viscosity of the drilling fluids and by sealing the walls of the borehole due to its long chains of monosaccharide, has been using in the NDDF. PGS works excellently as the fluid loss control agent in NDDF which also has a moderate role in controlling the rheology of the mud.

But, the PGS is limited to low temperature i.e. shallow depth. The Poly Anionic Cellulose (PAC) is also a fluid loss reducer and coating agent in fresh and salt water used as a high temperature and biodegradation resisting component in the NDDF. It also works excellently as the rheology and Fluid Loss control agent in NDDF which also has a moderate role in controlling the Mud Cake Thickness. (Prasenjit and Subrata, 2015b)

But, all these materials (XC-Polymer, PGS and PAC) are highly biodegradable. After few days of formulation all those starts degrading and adversely affects the mud properties. Therefore, the drilling time using NDDF should be as low as possible or the drilling rate in the pay zone should be as high as possible. The biodegradable nature of these materials is necessary for reducing the formation damage by removing the pore-plugging if occurred and for the environmental protection. But, the biodegradation during the drilling is disadvantageous for us. It will degrade the properties of mud builds up due to the presence of these materials. So, we must have to use the biocide to decrease the degradation rate of these materials during the drilling.

MATERIALS AND METHODS

MATERIALS

The general components used for formulation of NDDF are:

1. Base fluid: Fresh water
2. Viscosifier: XC-Polymer
3. Fluid loss control agent: PGS (Pre Gelatinized Starch), PAC (LVG) & PAC (RG)
4. Formation clay/shale inhibitor: Potassium Chloride (KCl)
5. Weighing and bridging materials: Medium Coarse $CaCo_3$ and Micronized $CaCo_3$
6. pH control agent: Caustic Soda (NaOH)
7. Bactericide (Formaldehyde) to control the bacterial degradation of Polymer/Starch used

To study the role of Bactericide, the NDDF is prepared by properly mixing the mixture of Fresh Water: 1.5 Litre, XC-Polymer: 0.25%, PGS: 2.5%, PAC (LVG): 0.4%, PAC (RG): 0.3%, NaOH: 0.025%, MCC: 4.5 %, MCCC: 3%, KCl: 5% and varies the composition of Biocide. [Prasenjit and Subrata, 2015a, 2015b, 2015c and 2015d; Appa A. Rao and A. K. Pandey, 2010; S. K. Chattopadhyay *et al*., 2010.]

As discussed earlier, the drilling fluids are designed based upon the formation characteristics. Therefore, to study the detail characteristics about the reservoirs and drilling operations of the study area, some data of reservoir rock properties, some mud policy & well cards of drilled wells using NDDF are collected from different operating companies working in this basin. Moreover, some mud chemicals also collected from the operating companies for performing the experiments in the laboratories.

METHODS

Firstly, according to proper measuring manual instructions six (06) numbers of NDDF samples were formulated by varying the composition of Biocide as 0%, 0.05%, 0.1%, 0.15%, 0.2% and 0.25% keeping the other components as fixed taking their optimum composition for the study area according to the previous researchers using the following equipments:

1. Mettler Electronic Precision balance to measure the mass of different chemicals for proper composition.
2. 1000 ml measurable stainless steel cup for measuring the water volume.
3. Hamilton Beach Mixer for proper stirring/mixing water and the mud component for generation of proper mud properties.
4. 15 ml pipette to measure small liquid volume.

Then, the effect of varying composition of Biocide on mud properties were investigated to select the optimum percentage of Biocide which will give best resistance to biodegradation of the XC-Polymer, Pre Gelatinized Starch and Poly Anionic Cellulose used in NDDF basically to control the rheological properties and fluid loss of drilling fluid; and thus maintain these properties in the optimum range.

To investigate the effect of varying composition of Biocide on the various mud properties, the formulated NDDF samples were kept in the laboratory for thirty (30) days and investigate the rheological and fluid loss properties in regular manner for a duration of Five (05) days using the following equipments:

a) OFITE plastic Marsh Funnel Viscometer to measure the Funnel Viscosity of formulated mud.
   In this equipment, the viscosity is reported in seconds allowed to flow out of the funnel. API specifications call for 1500 ml and one quart (946) ml out. For API water at $70^oF + 0.5^oF = 26 + 0.5$ sec. It measures the apparent viscosity**.** (PETE, 2003)
b) OFITE model 800 Viscometer to measure/determine Plastic Viscosity, Yield Point, Gel Strength (Gel_0) of formulated mud.
   For determining the Apparent Viscosity, Plastic Viscosity and Yield Point, the following formulas have been used:
   Plastic Viscosity = (θ600- θ300) CP
   Yield Point = (θ300- PV) lb/100ft^2. (PETE, 2003)
c) Filter Press for measuring the Fluid Loss of formulated mud.

The loss of liquid from a mud due to filtration is controlled by the filter cake formed of the solid constituents in the drilling fluid. Filter press used for filtration tests. The test in the laboratory involves measuring the volume of liquid forced through the mud cake into the formation drilled in a 30 minute period under given pressure and temperature. The low pressure test is made under the API condition of 100 ± 5 psi for 30 minutes at room temperature. (PETE, 2003)

Secondly, the Mean and Median of the different NDDF parameters of successfully drilled wells in the producing formations of the major oilfields of Upper Assam Basin were calculated from the well-cards of the completed wells collected from different operating companies of this basin to design the optimum mud parameters for the successful wells in terms of drilling and production in this basin.

Finally, tabulated the results and made some graphs of the fluid loss and rheological properties and investigated the mud parameters of NDDF. Then analysed the results and graphs and examine the effect of Bactericide to control biodegradation of the XC-Polymer, Pre Gelatinized Starch and Poly Anionic Cellulose used in Non Damaging Drilling Fluid and an effort has been made to optimize the composition of Bactericide. Moreover, a study for the best duration of drilling using NDDF without much biodegradation besides using the biocide was done based on the required/ designed range of the mud parameters for successful wells in the Upper Assam Basin.

RESULTS AND DISCUSSION

As discussed above, six (06) numbers of NDDF samples were formulated by varying the composition of Biocide as 0%, 0.05%, 0.1%, 0.15%, 0.2% and 0.25% keeping the other components constant as Fresh Water: 1.5 Litre, XC-Polymer: 0.3%, PGS: 3%, PAC (LVG): 0.4%, PAC (RG): 0.3%, NaOH: 0.025%, MCC: 4.5 %, MCCC: 3%, and KCl: 5% using the above mentioned equipments.

Table-01 Properties of the formulated NDDF at different composition of Bactericide (Biocide) with increasing duration

Biocide, (%) →	Days ↓	Funnel Viscosity, Seconds						Plastic Viscosity, CP						Gel Strength (Gel_0), lb/100ft^2						Yield Point, lb/100ft^2						Fluid Loss, ml					
		0	0.05	0.1	0.15	0.2	0.25	0	0.05	0.1	0.15	0.2	0.25	0	0.05	0.1	0.15	0.2	0.25	0	0.05	0.1	0.15	0.2	0.25	0	0.05	0.1	0.15	0.2	0.25
	0	55	55	55	55	55	55	17	17	17	17	17	17	9	9	9	9	9	9	21	21	21	21	21	21	6.7	6.7	6.7	6.7	6.7	6.7
	5	47	52	53	54	54	55	7.7	15.8	16.7	17	16.9	17	5	7	8	9	9	9	9.7	19.3	20.5	21	21.2	21.1	10	8.2	7.5	7.2	7.2	7.3
	10	40	43	50	51	52	52	4.9	13.9	16.1	16.4	16.5	16.5	4	5	7	8	8	8	6.3	15.8	17.5	20.1	20.2	20.1	11.1	8.9	8.1	7.5	7.4	7.5
	15	34	42	44	45	46	46	3.7	10.2	14.3	15	14.9	15	3	4	7	8	8	8	5.2	12.1	14	17	16.9	17	11.2	9	8.3	7.6	7.7	7.7
	20	30	38	40	41	41	41	3	8.1	12.4	13.2	13.2	13.1	2	3	6	7	7	8	4.7	10.7	11.5	14.1	14	14	11.5	9.1	8.4	7.8	7.7	7.8
	25	29	37	35	40	40	41	2.7	7	11.4	12	12.1	12	2	3	6	7	7	7	4.3	10.1	11	12.3	12.2	12.3	11.9	9.2	8.5	7.9	7.9	7.9
	30	27	35	38	38	39	39	2.3	6.5	11.2	11.7	11.8	11.7	1	3	5	6	7	7	4.1	9.8	10.9	11.9	12.1	12	12.3	9.3	8.5	7.9	8	7.9

To investigate the effect of varying composition of Biocide on the various mud properties, the formulated NDDF samples were kept in the laboratory for thirty (30) days and investigate the rheological and fluid loss properties in regular manner for a duration of five (05) days using the above mentioned equipments.

Then, mud properties were investigated and accordingly tabulated the results and made some graphs of the mud properties. Then, analysed the results and graphs and examine the effect of Bactericide to control biodegradation of the XC-Polymer, Pre Gelatinized Starch and Poly Anionic Cellulose used in Non Damaging Drilling Fluid to control the fluid loss and rheological properties and select the optimum percentage of Biocide which will give best resistance to biodegradation.

From Table-01, we can investigate that the biodegradation rate of the sample without adding Biocide is very fast. The XC-Polymer, Pre Gelatinized Starch and Poly Anionic Cellulose used in Non Damaging Drilling Fluid are highly biodegradable in nature; which is a positive side for a NDDF since the plugged pores by these Polymers and Starch while drilling will be opened up automatically due to their degradation by bacterial action after few days. Moreover it is a positive side for the environmental pollution also. But, the rapid degradation during drilling is unfavourable for drilling. The rapid degradation happens in the NDDF sample without biocide makes the mud unsuitable for drilling operation. The rheological properties e. g. Plastic Viscosity, Funnel Viscosity, Yield Point, Gel Strength etc. and the Fluid Loss characteristics of NDDF are basically responsible for the presence of the Polymers and Starch. These materials are highly degradable by the bacterial activities and in turn affect adversely on fluid loss and rheological properties of the NDDF as seen from the Table-01. Then, the Mean and Median of the different NDDF parameters of successfully drilled wells using NDDF in the pay-zone sections of the producing formations of Upper Assam Basin were calculated (Table-02) from the well-cards of the completed wells collected from different operating companies of this basin to design the optimum mud parameters for successful wells in this basin. From the Table-02, the designed values for Funnel Viscosity, Plastic Viscosity, Yield Point, Gel Strength (Gel_0) and Fluid Loss required for successful drilling operation in the study areas are 51.1 ± 5 Seconds, 13.8 ± 5 CP, 29.3 ± 10 lb/100ft^2, 9.6 ± 4 lb/100ft^2 and 6.3 ± 2 ml respectively.

From the Table-01, the values for Funnel Viscosity, Plastic Viscosity, Yield Point, Gel Strength (Gel_0) and Fluid Loss of the NDDF sample on fifth day of formulation are 47 Seconds, 7.7 CP, 9.7 lb/100ft^2, 5 lb/100ft^2 and 10 ml respectively. Among these properties, the Funnel Viscosity and Plastic Viscosity are just comes to the required range and the others are not within the range. That means we must have to complete the drilling operation of the target section within approximately five days of drilling using the NDDF in the Upper Assam Basin and which is not practically possible in most of the cases.

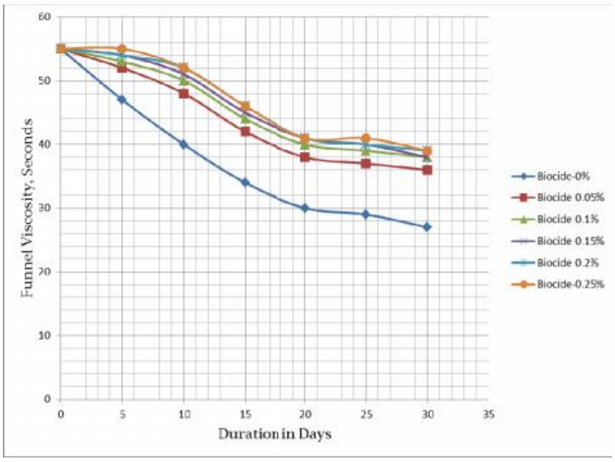

Figure 1 Change in Funnel Viscosity of NDDF with different composition of Biocide vs. Duration

Table-02 NDDF parameters of Sixteen successfully drilled wells in producing formations of Upper Assam Basin

Well Name	Well's Brief Description	Specific Gravity	NDDF Parameters: Funnel Viscosity, Seconds	Fluid Loss, ml	Plastic Viscosity, CP	Yield Point, lb/100ft^2	Gel Strength (Gel_0), lb/100ft^2	Gel Strength (Gel_{10}), lb/100ft^2
XYZ-1	Development well, Inclined (L) profile, 2617 m TVD	1.07-1.08	55-59	5-8	11-16	30-36	8-10	16-18
XYZ-2	Development well, Inclined (L) profile, 2880 m TVD	1.06-1.07	42-55	7-8.5	11-14	16-24	6-8	11-16
XYZ-3	Development well, Inclined (L) profile, 2900 m TVD	1.08-1.11	53-60	5.5-6.2	14-19	25-35	6-7	10-13
XYZ-4	Development well, Inclined (L) profile, 2900 m TVD	1.08-1.12	47-57	4.2-7	10-17	35-38	8-12	15-18
XYZ-5	Development well, Inclined (L) profile, 3051 m MD	1.08-1.12	43-50	3.4-7.6	9-18	22-37	8-12	10-17
XYZ-6	Development well, Inclined (L) profile, 3010 m TVD	1.08-1.12	45-50	4.5-6.5	12-20	23-36	7-12	14-22
XYZ-7	Development well, Inclined (S) profile, 3150 m TVD	1.09-1.11	45-49	5.5-6.0	11-18	20-28	7-11	14-16
XYZ-8	Development well, Horizontal profile, 3258 m TVD	1.04-1.06	54-60	8-10	7-14	26-40	10-15	27-48
XYZ-9	Development well, Inclined (L) profile, 3569 m TVD	1.12-1.18	42-47	5.7-6.5	10-17	19-25	5-7	11-17
XYZ-10	Development well, Inclined (L) profile, 3600 m TVD	1.08-1.09	53-58	6-8	10-12	32-42	10-13	17-20
XYZ-11	Development well, Inclined (L) profile, 3850 m TVD	1.14-1.20	50-55	4.6-5.8	14-19	24-43	9-12	15-19
XYZ-12	Development well, Horizontal profile, 3085 m TVD	1.05-1.07	45-50	4-6	13-16	23-28	7-9	13-15
XYZ-13	Development well, S-profile, 3500m TVD	1.06-1.15	45-52	5.5-9	10-16	18-37	8-9	12-18
XYZ-14	Development well, Horizontal profile, 2477 m TVD	1.10-1.14	48-52	5-7	11-18	24-28	9-12	24-30
XYZ-15	Development well, Inclined (L) profile, 4250 m TVD	1.08-1.18	44-65	4.6-8.6	12-18	14-39	8-18	15-51
XYZ-16	Development well, Horizontal profile, 3073.5 m TVD	1.04-1.06	51-57	8-8.5	13-15	29-36	10-12	16-18
	Mean	1.09	51.16	6.43	13.91	29.13	**9.53**	**18.63**
	Median	1.10	51	6.05	13.75	29.5	**9.75**	**16.75**
	Designed Value	1.09 ± 0.05	51.1 ± 5	6.3 ± 2	13.8 ± 5	29.3 ± 10	**9.6 ± 4**	**17.5 ± 5**

(Prepared from Well-Cards collected from different operating companies of Upper Assam Basin)

Thus, we must have to decreases the biodegradation rate of the mud during the drilling using NDDF. Therefore, the biocide has a great role in NDDF to decrease the degradation rate of the Polymers and Starch and retain the mud properties within their optimum ranges.

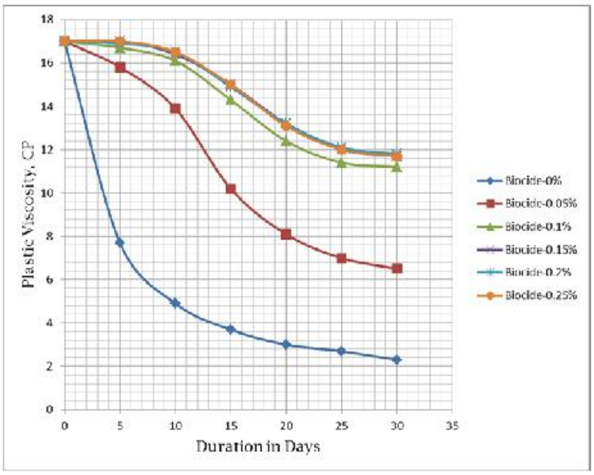

Figure 2 Change in Plastic Viscosity of NDDF with different composition of Biocide vs. Duration

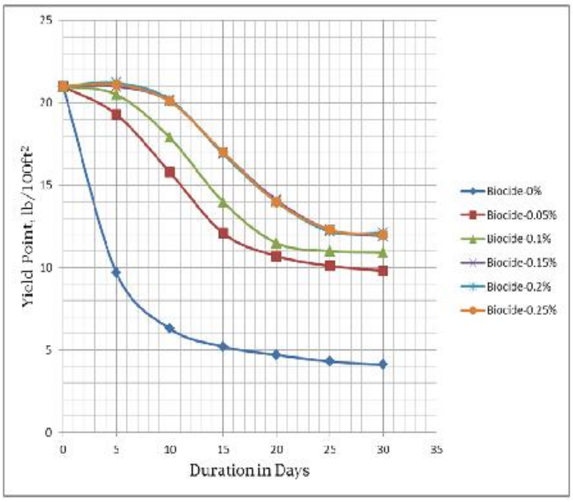

Figure 3 Change in Yield Point of NDDF with different composition of Biocide vs. Duration

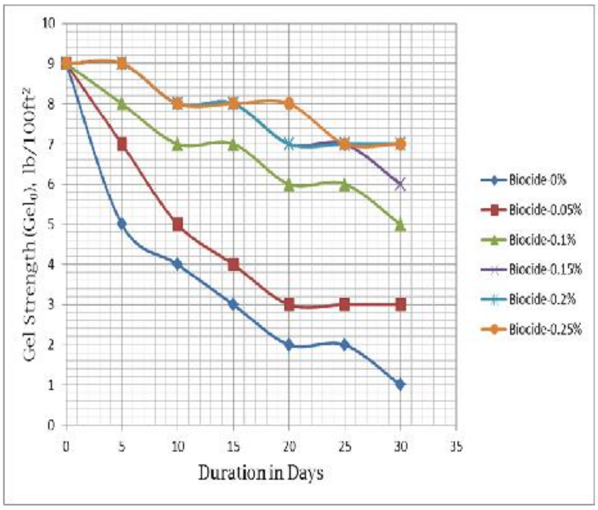

Figure 4 Change in Gel Strength of NDDF with different composition of Biocide vs. Duration

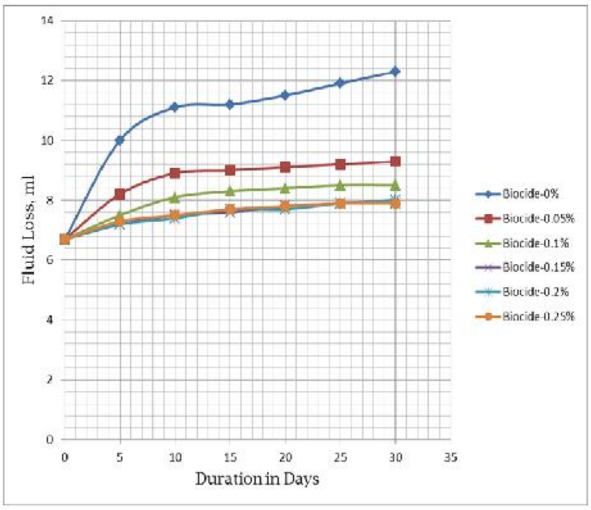

Figure 5 Change in Fluid Loss of NDDF with different composition of Biocide vs. Duration

It is can be clearly investigated from the Table-01and Figure 1-5 that when the composition of the Biocide increases from 0%, the biodegradation rate also slows down. Even a very small composition e.g. 0.05% of Biocide has a great effect on the biodegradation rate. But, it has been seen that the degree of effect of the increasing composition of Biocide from about 0.1% of Biocide is retarded. From 0.15% of Biocide, all the higher compositions are showing nearly same effect on controlling the biodegradation and retaining the mud properties. All the NDDF with higher composition of Biocide are showing the nearly same characteristics. In the Figure 1-5, we have seen that the three curves for Biocide-0.15%, Biocide-0.2%, and Biocide-0.25% are almost overlapping each other for all the five mud properties. That means there is no need of the higher composition of Biocide above the 0.15%. Thus, we can recommend the 0.15% of Biocide as the optimum composition for controlling the biodegradation in the NDDF.

Moreover, there is one important point that can be noticed from the Table-01 that even after the addition of the optimum composition of Biocide in the NDDF, the properties are degraded with the increasing time span. Initially, the degradation rate is rapid and gradually the rate decreases with the increasing time. From the Table-01, it can be investigate that all the designed mud parameters according to the Table-02 for the successful wells in the Upper Assam Basin lies upto the fifteen (15) days of duration. At fifteen days of duration the values for Funnel Viscosity, Plastic Viscosity, Yield Point, Gel Strength (Gel_0) and Fluid Loss of the NDDF sample with the Biocide composition of 0.15% are about 46 Seconds, 15CP, 17 lb/100ft^2, 8 lb/100ft^2 and 7.7 ml respectively. All these values of the mud parameters nearly come within the designed range of the values of required mud parameters for the Upper Assam Basin. But, after fifteen days, we have seen that the values for the mud parameters come out of the designed values. That's why we may recommend the maximum drilling time for the drilling of the pay-zone using NDDF even with the Biocide should not exceeds more than fifteen days for the Upper Assam Basin.

CONCLUSION

From the above discussion, the following conclusions are drawn:

- The rheological properties e. g. Plastic Viscosity, Funnel Viscosity, Yield Point, Gel Strength etc. and the Fluid Loss characteristics of NDDF are basically responsible for the presence of the Polymers and Starch. But, we have seen that the Polymers and Starch are highly degradable by the bacterial activities and in turn adversely effects on fluid loss and rheological properties of the NDDF. A rapid degradation happens in the NDDF without biocide and makes the mud unsuitable for drilling operation. Therefore, we must have to decreases the biodegradation rate of the mud during the drilling using NDDF. The biocide has a great role in NDDF to decrease the degradation rate of the Polymers and Starch and retain the mud properties within their optimum ranges. Even a very small composition e.g. 0.05% of Biocide has a great effect on the biodegradation rate.
- All the reservoirs in the world are heterogeneous. The properties and characteristics are different in different location in the reservoir. Therefore, the composition of any component or the value of any properties of NDDF to serve any function will not be fixed. In this study, from the laboratory experiments we have seen that all the higher compositions of Biocide after 0.15% are showing nearly same effect on controlling the biodegradation and retaining the mud properties. Based on the laboratory experiment, we can recommend the about 0.15% of Biocide as the optimum composition for controlling the biodegradation in the NDDF.
- The maximum drilling duration for the drilling of the pay-zones of Upper Assam Basin using NDDF even with the Biocide should not exceeds more than fifteen days according to the study based on laboratory experiments and field data of successful wells using NDDF.
- Intensive care of the mud and the circulation system is needed during drilling the pay zone section. All the solid control equipments e.g. Shale shaker, De-Sander, De-Silter, Mud Cleaner, etc. should be working properly during the drilling to control the solid particles in mud. Continuous investigation of the properties and functions of the mud, whether they are fulfilling the requirements or not, is necessary and if required we may have to change the composition of the mud during drilling.
- The best wells are often the ones where we expose the formation to the mud system for the least amount of time, no matter what kind of fluid is being used.

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