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Effects of Combined Water and Clay Contaminants on Drilling Mud Properties used in Uquo Formation , Akwa Ibom State, Nigeria.

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ABSTRACT

Uquo field is situated in Oil Mineral Lease (OML) 13 in Akwa Ibom State Nigeria. The field formations comprises of Akata, Agbada and Benin formations with the Agbada formation being the main hydrocarbon bearing zone of the Niger Delta basin. Hence, the choice of drilling fluid is critical to the success of the venture which needs to be formulated in line with the suitably designed mud program. This paper investigates the outcome of combined effects of equal amount of water and clay contamination on drilling fluids performance. Pre-formulated drilling fluids were separately contaminated with 5% clay + 5% water, 10% clay + 10% water and then subjected to tests for key parameters. America Petroleum Institute (API) standards were employed for the analysis. A combination of (5% clay + 5% water) or (10% clay + 10% water) caused an increase in the mud weight, rheological properties and fluid loss of the mud system while emulsion stability and oil - water ratio decreased. This imposed shortcomings leads to swelling clay, tight hole problems, torque and drag, and stuck pipe that increases operational cost as well as cause formation erosion and loose water interacting with formation clays, a precursor to tight hole problems, reduced lubricity, that culminated into torque and drag phenomena. The results indicated that the presence of contaminants in the drilling mud affects the characteristic of the mud system, influence the performance of the mud which is a precursor to drilling difficulties.

Key words: Uquo Field, OML 13, drilling fluid, Mud rheology.

Introduction

Uquo field is situated in Oil Mineral Lease (OML) 13 in Akwa Ibom State, South Eastern part of the Nigerian Niger Delta. Generally, The State is generally a plain land with networks of rivers, streams and creeks emptying into the Imo River and the Atlantic Ocean. Uquo field consists of a flat to moderately rippling sandy plains, stone hills and ravines with occasional V- shaped valleys. The tertiary Niger Delta has been described to be a sedimentary basin formed as a complex regressive offlap sequence of classic sediments with thickness ranging between 9,000 and 12,000 meters (Usoro, 2010, Nwankwoala and Udom, 2011)). Uquo field formations is a combination of Akata, Agbada and Benin formations. The Akata formation (brownish shales and exposed marine facies representing low marine depositional settings) is the foundational unit with thickness of 0 to 6,000 meters approximately. The Agbada formation overlays the Akata formation which is reported to be the principal crude oil bearing zone of the Niger Delta basin and consists of sandstone and shales with thickness of over 3000 meters. Agbada formation is overlaid by the Benin formation estimated to be 0 to 2,100 meters thick according to Etu-Efeotor and Akpokodje, (1990) and Ehibor et al., (2019).

Drilling through these formations for oil and gas resources is an expensive venture. It therefore requires intensive planning and choice of materials especially the drilling fluid system which must meet the specification of the mud program developed from knowledge characterisation of the formation. Basically, the purpose of the drilling fluid consist of borehole bottom cleaning, movement of drill cuttings to the surface, lubrication and cooling of drill bit system, wellbore wall support by mud cake layer and provision of hydrostatic pressure that prevents formation fluids intrusion into the well (Van Dyke, 2000; ASME, 2005). However, during drilling operations, a lot of contaminants are encountered depending on the formation characteristics. These contaminants tend to lower the efficiency of the drilling mud. The substances that reduces the efficiency of drilling fluids are materials that alters the drilling fluid characteristics (mud weight and other rheological parameters) which finds their way into the mud system during drilling operations (Achadu et al.,2023) These contaminants affect the mud compositions thereby altering its performance negatively. Generally, these pollutants could be attributed to the parent formation, effect of temperature on mud organics, as well as improper treatment. Mitchell and Lake (2006) listed the main contaminants of drilling mud as calcium-ions, salt/saltwater flows, bicarbonate and carbonate as well as hydrogen sulphide. Calcium ions originates from water (makeup and formation), mixed salt formations as well as drilling cement or anhydrite. It replaces the N^{+} on the clay surface through ion exchange mechanism. This phenomena results in unfavorable alteration in key mud properties. Generally, the main constituents of saltwater are Na^{+} and Cl^{-} and usually interferes with the mud system in operation when the formation contains high amount of salt or seawater in off shore locations. This influx influences the mud system yield point, fluid loss and pH levels negatively. On the other hand, drilling CO_2 bearing zones are the main origins of bicarbonate and carbonate contaminant ions (CO_{2-3}, HCO_3) while overtreatment of mud system contaminated by other contaminants with soda ash could lead to carbonate alkalinity.

2. MATERIALS AND METHODS

2.1. Materials

The main materials used for this article consists of clay, water and pre- formulated drilling fluid.

2.2. Sample Preparation

Drilling fluid was formulated and contaminated with equal amount of water and clay (similar to the location). Samples of the drilling fluid contaminated with 5% clay + 5% water and 10% clay + 10% water were prepared separately.

2.3. Determination of mud weight, emulsion stability, rheological properties, gel strength, fluid loss and oil- water ratio

The procedure for the determination of mud weight, emulsion stability, rheological properties, gel strength, fluid loss and oil- water ratio followed those methods specified in the study conducted by Achadu et al., (2023). The processes were repeated for all the mud samples (with 5% clay + 5% water, 10% clay + 10% water contamination).

3.0. RESULTS AND DISCUSSION

The results of the drilling fluid contaminated with equal amount of water and clay are detailed in Table 1.

Table 1: Characteristics of drilling mud contaminated with equal portion of clay and water.

			Percentage water and clay		**Percentage clay** Osadolor et al.,(2022)		**Percentage water** Achadu et al.,(2023)		
Parameters		**Base mud**	**5% + 5%**	**10% + 10%**	**5%**	**10%**	**5%**	**10%**	**Control (Mud Program**
Mud weight (lb/gal)		9.5	9.7	9.9	9.8	10.0	9.42	9.4	9.0 – 10.0
ES (volts)		405	314	228	385	370	360	297	> 350
		Shear stress (N/M^2)							
Rheological properties	600 rpm	77	102	125	98	110	97	111	
	300 rpm	52	67	81	64	72	64	73	
	200 rpm	44	55	67	52	59	52	58	
	100 rpm	33	37	48	37	42	38	41	
	60 rpm	27	27	32	32	35	33	34	
	30 rpm	17	23	26	20	22	20	23	
	6 rpm	13	16	19	15	18	14	17	12 – 14
	3 rpm	13	15	18	15	17	14	16	
	10 (s)	17	21	24	19	20	19	21	17 – 20
	10 (m)	27	30	33	29	32	29	31	24 – 27
PV (cP)		25	35	44	34	38	33	38	15 – 25
YP (lb/100ft^2)		27	33	37	30	34	31	35	24 – 28
Rs (%)		21	23%	25%	23%	25%	18	15	
Ro (%)		52	48%	45%	52%	52%	52	52	
Rw(%)		27	29%	30%	25%	23%	30	33	
OWR		66/34	62/38	60/40	68/32	69/34	63/37	61/39	65/35 – 70/30
HTHP FLmls		5mls	13.0ml Water = 4.6ml	14.0ml Water= 5.8ml	5.4ml	10.6ml	9.2mls	9.8mls	5mls

ES= Emulsion Stability, measured in volts. PV= Plastic Viscosity in centipoise (cP). YP= Yield Point in lb/100ft^2. Rs=Ratio of solids in percentage (%), Ro= Ratio of oil in percentage (%), Rw= Ratio of water in percentage (%), OWR= Oil- water ratio. HTHP FL= High Temperature High Pressure Fluid loss in ml.

3.1.Mud Density

The mud density values recorded for equal water and clay (5% water + 5% clay and 10% clay + 10% water) were 9.7 lb/gal and 9.9 lb/gal respectively. These values were within the range reported by Osadolor et al., (2022), and Achadu and osadolor, (2023) for individual 5%, and 10%. However, the recorded values are slightly less than the values reported for clay contamination but more than values recorded for water individual contamination. The values were however within the control value 9.5 lb/gal and the mud program specification (9.0 – 10.0 lb/gal). This implied that combined low percentage water and clay contamination has insignificant effect on the performance of the drilling fluid.

3.2. Emulsion Stability (ES)

The values of ES is the increase in voltage across a probe until the emulsion breaks and current is established. The ES values recorded were 314 v and 228 v for combine contaminations (5% clay + 5 % water and 10% clay + 10% water) respectively. The values were significantly less than the values reported by Osadolor et al., 2022, and Achadu and osadolor, 2023 for individual contaminations (385 v and 370v) for 5%, and 10%, clay contaminations while 360 v and 297 v were reported for 5% and 10% water contaminations respectively. These recorded values were all less than the values reported for individual clay and water contaminations as well as that of the control value 405v and the mud program specification of > 350 v. This phenomenon indicated that the contaminations affects the functionality of the drilling fluid.

3.3. Rheological Properties

Rheology of drilling fluid is attributed to the combined properties arising from the various components that make up the drilling fluid system. The basic rheological properties include gel strength, shear stress, yield point and viscosity. 6 -speed instrument allows different speeds in rpm (3, 6, 100, 200, 300 and 600). Plastic viscosity (PV) and yield point (YP) are usually estimated from the reading of this instrument. These speeds display on viscometer depicts the flow characteristics of the drilling fluid as it circulates about the drilled formation. While the 600 rpm portrays the flow performance around the drill bit, the least rpm indicates a high diameter annulus. PV measures the flow resistance in relation to inter-particle friction which can be attributed to the quantity, size and shape of the solids in the mud sample as well as the viscosity of resulting liquid phase. The value of PV the difference between the 600rpm and that of the 300rpm reading of viscometer as shown in Equation 1.

$$PV = (\Theta 600 \text{ rpm}) - (\Theta 300 \text{ rpm}) \quad \ldots\ldots 1$$

The PV value of the base mud was 25cP, while values for 5% clay + 5% water and 10% clay + 10% water contaminations were 35cP and 44cP respectively. The increase in PV occasioned by the increase in clay and water contaminations is in line with the results reported by Biwott et al (2019), Kumapayi et al., (2014) and Mahmud (2016) who reported that an increase in cement concentration led to an increase in PV value. These values were however higher than results reported by Adekomaya (2013) and Yunita, et al (2017). The mud program specified a range of 15 – 25 cP for PV. This implied that the PV values of all the combined contaminated mud samples were outside the acceptable range. The recorded values implied that an increase in combined clay and water contaminations resulted in the increment of the PV levels of the mud due to the ability of clay and water to cause the mud system more viscous.

3.4. Yield Point (YP)

Yield point (YP) is the force applied to a material for flow to begin. The value of YP is employed for predicting the possibility of hole cleaning near high shear zones because it consists of high shear rate viscosity levels. YP is estimated by PV from the 300rpm dial reading of the viscometer instrument as shown in Equation 2.

YP = 300 rpm reading – PV…………………………………..2

The YP value of the base mud was 27 lb/100ft^2, while 33 lb/100ft^2 and 37 lb/100ft^2 were values obtained after 5% clay + 5% water and 10% clay + 10% water contaminations respectively. The values reported by Biwott et al (2019) and Kumapayi et al, (2014) corroborated values obtained in this study. The values recorded for YP followed the trends displayed by other properties of the mud samples; increase of YP with corresponding increase in mud contamination. However, the acceptable value for YP was in the range (24 lb/100ft^2 - 28 lb/100ft^2), implying that all the values obtained after contaminations were greater than the specified range of values. It can therefore be inferred that an increase in combined clay and water intrusion into the mud system results in increment of the attractive forces that aggregates the particles and thereby increase the number of charges which is a precursor increase Yield Point.

3.5. Shear Stress

The shear stress from 3-rpm reading values recorded were 15 cP and 18 cP for the combined contaminations (5% clay + 5 % water and 10% clay + 10% water) respectively. The values reported by Osadolor et al., (2022) and, Achadu and Osadolor, (2023) for individual contaminations were 15 cP and 17 cP for 5%, and 10%, clay contaminations respectively and 14 cP and 16 cP for 5% and 10% water contaminations respectively. These recorded values for clay-water combined contaminations were all higher than the values reported for individual clay and water contaminations as well as that of the control value 13 cP though not specified in the mud program. This rheological parameter is an illustration of the mud rheology bordering the formation and provides an idea of the neatness of the drilled hole (Achadu and osadolor, 2023).

The shear stress from 6-rpm reading values recorded were 16 cP and 19 cP for the combined contaminations (% clay + 5% water and 10% clay + 10 water) respectively. The values reported by Osadolor et al., 2022, and Achadu and osadolor, 2023 for individual contaminations were 15 cP and 18 cP for 5%, and 10%, clay contaminations respectively, 14 cP and 17 cP for 5% and 10% water contaminations respectively. It was observed that the values of 6-rpm reading increased with an increase in the mud contamination, this trend was also observed in individual clay and water contaminations respectively. However, the acceptable reading for 6-rpm is (12-14cP), hence the base mud of value 13 was on specification while others were off specification. The increase of the 6-rpm reading of the mud system could be attributed to the thickening effect of the clay and water which made the mud more viscous thereby causing an increase in the rheological values of the mud. The values recorded implied that combined contamination has greater effect on drilling fluid and reduces the efficiency of the mud system.

3.6. Other Shear Stress components

The 600 rpm depicts the flow behavior around the drill bit during drilling operations. The values recorded from the study were 77 N/M^2, 102 N/M^2 and 125 N/M^2 for control drilling fluid, 5% clay + 5% water and 10% clay + 10 water contaminated drilling fluid respectively. This values were higher than values reported by Achadu and Osadolor, 2023 and Osadolor et al., 2022. Similar trend was noted for the other components of shear stress (300 rpm, 200 rpm, 100 rpm, 60 rpm, and 30 rpm). This implied that combined contamination is more detrimental to individual contamination. However, there was no specification in the mud program.

3.7. Gel Strength

The gel strength is described as the shear stress of the drilling mud estimated at a minimal shear rate after the drilling mud is allowed to settle within a specific period. The gel strength implied the capability of the mud to suspend drill solids as well as the weighting substances when circulation stops. It show the propensity of the mud to form a gel after a long period of time. Gel strengths, (10-seconds and 10-minutes), implied the strength of the attractive forces during gelation of drilling fluid under static state. The 10-seconds gels reading for the base mud was 17 $lb/100ft^2$, while those for 5% clay + 5% water, 10% clay + 10% water contaminated samples were 21 $lb/100ft^2$, and 24 $lb/100ft^2$ respectively. The values for 10-seconds gels obtained in this study corroborates with the values reported by Biwott et al (2019), Shadravon (2012) and Broni- Bediako, et al (2019), but greater than values reported by Yunita, et al. (2017). The values of 10-seconds gels increased progressively from 17 $lb/100ft^2$ (0% contamination) to 24 $lb/100ft^2$ after 10% clay + 10% water contaminations in line with values reported by Osadolor et al., 2022, Achadu and osadolor, 2023 and Achadu et al., 2023 in the individual clay and water contaminations study. The control range for 10- seconds gels is (17 $lb/100ft^2$ - 20 $lb/100ft^2$). Hence as specified in the mud program, the base mud was on specification, but values for the contaminated mud samples were out of specification. The result showed that 10- seconds gels value for the mud system increased with an increase in combined clay and water amount in the mud system. This could be attributed to excessive gelation resulting from high solids concentration. This result implied that the strength of the attractive forces (gelation) in the mud system under static condition increased with increase in the solids concentration of the mud system. The 10- minutes gels reading for base mud (control sample) was 27 lb/100ft^2, while 30 lb/100ft^2 and 33 lb/100ft^2 were obtained for 5% clay + 5% water and 10% clay + 10% water contaminations respectively. The mud program values for 10- minute gels was 24 lb/100ft^2 - 27 lb/100ft^2 and the results in Table 1 showed that only the base mud (27 lb/100ft^2) was within specified range, all the other values for the various contaminations were higher than the recommended range of values. The values for 10-minute gels showed a similar trend with 10-seconds gel values and also corroborates the works of Biwott et al (2019), Shadravon (2012) and Broni- Bediako, et al (2019), but higher than values reported by Yunita, et al. (2017).

3.8. Oil- water ratio (OWR)

OWR is the fraction of oil to water in a mud system and it provides the basic information needed controlling the mud properties. It is also important for designing and optimizing the solids control equipment. The OWR value of control mud sample was 66/34, while after 5% clay + 5% water and 10% clay + 10% water contaminations were 62/38 and 60/40 respectively. However, the levels obtained from mud program (reference) were in the range (65/35 – 70/30). Hence, the value after the combined contaminations was greater than the acceptable values. This showed that an increase in the clay and water contaminations combined leads to a decrease in the OWR which is detrimental to the mud system.

3.9. High Pressure High Temperature Fluid Loss (HPHT FL):

Control of filtration characteristics of drilling fluid are important indicators for adjusting fluid loss to formations and tight hole conditions. Usually, for a drilling mud subjected to critical testing conditions, these tests could be employed for expressing filtrate volume and loss filter cake quality. The HPHT value of base mud was 5mls, while the values for 5% clay + 5% water and 10% clay + 10% water contaminations were 13.0mls and 14.0mls respectively. A value of ≤ 5ml was specified in the mud program specified as the acceptable value for HPHT FL, but the values after the combined contaminations were greater than this specified value. This increase or deviations from the mud program may be attributed to the increase in clay and water reported which resulted to breakdown in the mud emulsion and allowed free water droplets in the mud system. This losses results in the increase in the fluid loss of the mud system. The outcome of this study corroborated the works of Yunita et al (2016), Mahmud (2016), Broni- Bediako et al (2019), Kumapayi et al., (2014), Shadravoin (2012) and Adekomaya (2013).

4.0. CONCLUSION

Mud specification depends on a number of parameters ranging from the nature of the well, soil condition, true depth and well performance. A combination of (5% clay + 5% water) and (10% clay + 10% water) caused an increase in the mud weight, but within the mud program specification. Clay and water incorporated into the mud system leads to a decrease in the mud's emulsion stability which is detrimental to drilling operation and leading to swelling clay, under gauged hole which in turn could lead to tight hole problems, torque and drag, and stuck pipe that increasing operation cost. Increase in rheological properties as a result of clay and water in the mud can cause formation erosion, and drilling difficulties like problems initiating flow, a drawback to drilling operation. A decrease in the oil- water ratio was observed (i.e. a decrease in the oil volume and an increase in the water volume), this causes drilling challenges like loose water interacting with formation clays, a precursor to tight hole problems, reduced lubricity, that culminates to torque and drag phenomena. The fluid loss of the mud system increased with an increase in the contamination, this is harmful to the drilling operation as too much fluid lost into the formation results in thick filter cake, culminating into tight hole problems, torque and drag, and stuck pipe. Conclusively, the presence of contaminants in the drilling mud either reduces or increases the properties of the mud system, and in turn affects the performance of the mud, and poses serious drilling problems. Therefore, for a drilling operation to be carried out safe and optimally, the driller and mud engineer must possess proper knowledge of the drilling mud chemistry, properties, and resulting contaminants and how to manage them.

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