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Beneficiation of Nigerian Clay with *Poly Anionic Cellulose-Regular (PAC-R)*

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Abstract

This paper documents the beneficiation of Nigerian clay from Emede in south south-Nigeria using PAC-R. The PAC-R was used in two concentrations and the effect of different concentration of Poly Anionic Cellulose-Regular (PAC-R) on the Emede clay was investigated. The experiment centred on the determination of its suitability for use in drilling mud formulation. Preliminary investigation suggests that Emede clay has a good potential for use in drilling operations when beneficiated appropriately.

Keywords: Niger delta sands, Emede clay, drilling mud

NOMENCLATURE

Property	Symbol	Formula For Calculating Rheological Properties of Drilling Mud	
Apparent Viscosity	AV	$AV = \theta600/2$	(1)
Plastic Viscosity	PV	$PV = \theta600/2 - \theta300$	(2)
Yield point	YP	$YP = \theta300 - PV$	(3)
Power law Index	n	$n = 3.32 \log(\theta600/\theta300)$	(4)

Where $\theta600$= 600 Dial Reading & $\theta300 = 300$ Dial Reading

1.0 Introduction

Clay deposits located in Emede forest, Delta state, Nigeria was analysed. A principal aim of the investigation was to determine and document the effect of different concentration of poly anionic cellulose regular (PAC R) on the Emede clay and its implication on drilling operations in the Niger Delta.

PAC R is a high viscosity, high molecular weight, poly anionic cellulose polymer designed to provide viscosity and reduce API filtration rate to water based drilling fluids; including freshwater, seawater, saturated saltwater and solids-free brines, native mud, flocculated mud and inhibited mud.

PAC R has the ability to increase and stabilize viscosity and hence improve rheology, wellhole cleaning and suspension property by coating and encapsulating cuttings and solids of drilling fluids. It is effective over a wide range of pH environments. It lubricates solids in the system, improves wallcake characteristics and reduces the potential for stuck pipe.

The primary rheological properties of interest to Mud Engineers are**:**

1. Viscosity
2. Gel strength
3. pH

These properties were investigated for drilling fluid designed using indigenous Nigeria (Emede) clay using API standards.

2.0 Location and Geological Setting of Study Area

Emede lies on the geographical coordinates of 5° 24' 0" N, 6° 11' 0" E.(Latitude and Longitude to decimals : 10.0 and 8.0 respectively in degrees minutes seconds Latitude and Longitude : 5° 24' 0" N 6° 11' 0" E and Latitude/Longitude to UTM Reference: UTM Northing:597602.518197571 Easting:187832.5305062626 Zone:32N) [1]. Emede is a very small little known village in Delta state, Nigeria. In most literature on clay deposits in Nigeria, little, if anything is mentioned about this remote village.

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The clay used in this investigation was harvested from a secluded and isolated forest (Figure 1) some few miles from the Oleh campus of the Delta State University Abraka.
Emede forest is characterized by heavy rainfall, humid condition with lush vegetation. Some areas in the forest are water-logged and the clay was retrieved from under a small mass of water. Emede is located in Isoko South local government Area of Delta state, Nigeria. (Figure 2)

Figure 1: Foot path into Emede Forest
Not much literature exists on the Emede Clay. This paper documents the effect of poly anionic cellulose regular (PAC R) on Emede clay collected from Emede forest (Figure 1) at a depth of4 feet from the surface.

Figure 2: Map of Delta state showing the various local government areas.

2. 0 Materials and Method

2.1 Apparatus

The apparatus used for the respective experiments are listed in Table 1.

Table 1: List of Apparatus

S/N	Apparatus	
1	Pioneer digital weighing machine	(Figure 3)
2	Hamilton beach mixer	
3	Fann viscometer model 35A	(Figure 8)
4	OFITE 4-scale metal mud balance(machined balance)	(Figure 7)
5	pH paper	(Figure 6)
6	Direct indicating viscometer	
7	Thermometer	
8	stop watch	

Samples of raw Emede clay were subjected to preliminary beneficiation treatment after it was dried at room temperature in the drilling laboratory of the University, pulverized; grinded into fine power and sieved with 200mm mesh device.

Figure 3: Pioneer Digital Weighing Machine

After drying and sieving (Figure 5), theEmede clay was blended with Wyomic bentonite to produce 11 different blends. Eachblend had a weight of 24.5 g. Each blend consistsof Emede clay and Wyomic bentonite mixed ina different proportion (Figure 4, Table3). 350 ml of fresh water was added to each preparation and thoroughly mixed using the Hamilton beach mixer. The pH was determinedusing pH paper (Figure 6, Table 2).

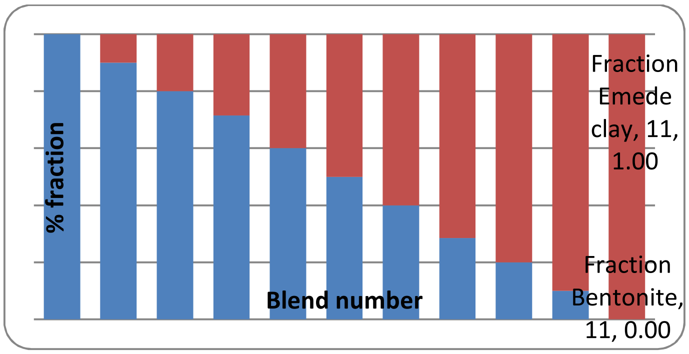

Figure 4: Blends and Compositions

Figure 5: API standard sieve

Table 2: Composition of the 11 Clay Blend Samples

Blend number	Emede Clay (g)	Wyomic bentonite (g)	Weight of Clay(g)
1	0.0	24.5	24.5
2	2.5	22.1	24.5
3	4.9	19.6	24.5
4	7.0	17.5	24.5
5	9.8	14.7	24.5
6	12.3	12.3	24.5
7	14.7	9.8	24.5
8	17.5	7.0	24.5
9	19.6	4.9	24.5
10	22.1	2.5	24.5
11	24.5	0.0	24.5

Table 3: The pH of the Various Blends

Blend number	Emede Clay (g)	Wyomic bentonite (g)	pH
1	0.0	24.5	9
2	2.5	22.1	8
3	4.9	19.6	8
4	7.0	17.5	9
5	9.8	14.7	8
6	12.3	12.3	8
7	14.7	9.8	7
8	17.5	7.0	7
9	19.6	4.9	6
10	22.1	2.5	5
11	24.5	0.0	6

Table 4: Grain Size Distribution

Grain size («*m*)	Percentage (%)
600	10
300	15
150	25
75	50

From the sieve analysis the particle size distribution was determined (Table 4).
The particle size distribution (or grain size distribution) is of importance as it can be used in understanding the transportation history of the respective constituent of the Emede clay.

Figure 8: OFITE 4-scale metal mud balance (machined balance)

Table 5: The Mud Density of the Blends

S/N	Specific Gravity	Pound Per Gallon(PPG)
1	1.04	8.6
2	1.02	8.4
3	1.04	8.6
4	1.04	8.6
5	1.04	8.6
6	1.04	8.6
7	1.03	8.5
8	1.03	8.5
9	1.03	8.5
10	1.03	8.5
11	1.03	8.5

Figure 7: Fann Viscometer Model: 355A

3.0 Procedure

STEP 1: The mud balance is calibrated with fresh water.
STEP 2: Remove the fresh water, clean and dry the mud balance.
STEP 3: The prepared mud is poured into the mud balance cup to the top and covered with the lid.
STEP 4: All spills are cleaned from the mud balance with a cotton towel.
STEP 5: The orifice is covered with your thumb and the mud cup gentlytapped toremove gas bubble.
STEP 6: The mud balance is placed on the knife edge.

STEP 7: The rider is moved and adjusted until the level bubble in the vial is stable between the inscribe lines.
STEP 8: The value is recorded.
STEP 9: The process is repeated for all specimens.

3.1 Viscosity

The rheological property; viscosity was studied using different concentration of poly anionic cellulose regular (PAC R).The Fann viscometer model 35A was used to determine the mud viscosity of the mud samples. In the petroleum industry, the Fann viscometer 35A is the principal device for the measurement of flow properties of drilling mud. The design has changed somewhat over the years and the current design, since 1955, consists of a coquette style viscometer with a wide gap of 1170 micron and a rotating outer cylinder calibrated such that the data at the low shear rates can be used to understand the performance of drilling mud at low shear rate as prevail in the wellbore annulus [1, 2].

It has long been recognised that drilling muds are not ideal plastic fluids. Several models exist, namely the Power Law, Herschel-Bulkley, Robertson-Stiff e.t.c.In the Power Law Rheological model there isthe introduction of the concepts of K, consistency factor and n, the consistency index, to describe the effects of the annular pressure loss and the hole-cleaning predictions [3, 4].

The viscometer is designed such that the 300rpm (θ300) gives a direct reading of the viscosity of a Newtonian fluid in centipoises or mPa. The 600rpm (θ600) dial reading less the 300 rpm dial reading denotes the Plastic viscosity (PV). The 300rpm reading less the PV provides the yield point (YP) [4, 5]. The YP is the initial resistance to flow caused by electrochemical forces between the particles. It is the yield stress extrapolated to a shear rate of zero [6].

Table 6: The Rheological Properties Of Each Blend

Blend	**Emede Clay (g)**	**Wyomic bentonite (g)**	**Rheological Properties**						
			θ600	θ300	AV	PV	YP	n	K
1	0.0	24.5	45	23	23	22.5	22	1.03	0.036
2	2.5	22.1	30	20	10	15	20	0.58	0.537
3	4.9	19.6	35	26	9	17.5	26	0.43	1.771
4	7.0	17.5	23	20	3	11.5	20	0.20	5.746
5	9.8	14.7	16	12	4	8	12	0.41	0.931
6	12.3	12.3	13	8.5	4.5	6.5	8.5	0.61	0.189
7	14.7	9.8	10	6	4	5	6	0.74	0.059
8	17.5	7.0	6	3.5	2.5	3	3.5	0.78	0.027
9	19.6	4.9	4	2	2	2	2	1.00	0.004
10	22.1	2.5	3	1.5	1.5	1.5	1.5	1.00	0.003
11	24.5	0.0	2.5	1	1.5	1.25	1	1.32	0.0003

Where:

θ600 The reading of the viscometer when 600 rpm
θ300 The reading of the viscometer when 300 rpm
AV Apparent viscosity
PV Plastic viscosity
YP Yield point
n consistency index
K Consistency factor
rpm Rotation per minutes

3.2 The Gel Strength

The gel strength is the shear stress measured at low shear rate after a period of quiescent. The API standard for the period of quiescent is 10 second and 10 minutes. It indicates the strength of attractive force under static conditions [6].

Table 7: The Gel Strength Of The Mud Blends

Blend	Emede Clay (g)	Wyomic bentonite (g)	10sec	10min
1	0.0	24.5	6	11
2	2.5	22.1	3	15
3	4.9	19.6	4	14
4	7.0	17.5	3	10
5	9.8	14.7	2	3
6	12.3	12.3	1	2
7	14.7	9.8	1.5	2
8	17.5	7.0	1.5	2
9	19.6	4.9	1.5	2
10	22.1	2.5	3	4
11	24.5	0.0	2	2

4.0 Experiment

The thrust of this paper involves the experiments undertaken to document of the effect of PAC – Ron Emede clay.
PAC-R is common viscosifying agent. It is added to the prepared mud to increase the viscosity of the mud. It is a derivative from starch. Polyanionic cellulose (PAC) retains fluid under high pressure and aid in the improvement of the rheological properties of the drilling fluid. In this investigation, the PAC-R was used in two concentration and the change in basic rheological properties noted**.**

4.1 Test Procedure On Viscosifying Agent Determination

PROCEDURE A:
STEP 1: 0.1g of poly anionic cellulose was measure with the Pioneer digital weighing machine (a digital weighing machine.)
STEP 2: the prepare mud was stirred and pour into the Waring mix blender.
STEP 3: the blender is switch on and the PAC R gently pour in the blended mud.
STEP 4: the blender is switch off and the mud is pour into the fann viscometer cup.
STEP 5: the fann viscometer is use to further determine the rheological properties and gel strength of the mud.
PROCEDURE B:
STEP 1: 0.2g of poly anionic cellulose was measure with the Pioneer digital weighing machine (a digital weighing machine.)
STEP 2: the prepare mud was stirred and pour into the Waring mix blender.
STEP 3: the blender is switch on and the PAC R gently pour in the blended mud.
STEP 4: the blender is switch off and the mud is pour into the fann viscometer cup.
STEP 5: the fann viscometer is use to further determine the rheological properties and gel strength of the mud.

5.0 Result and Discussion

Reading taken with viscosifying agent "PAC R" (poly avonic cellulose) additive 0.1g is shown on Table 8

Table 8: Reading with 0.1g viscosifying agent "PAC R" (poly avonic cellulose) additive using procedure A)

Blend Number	WYOMIC Clay (g)	EMEDE Clay (g)	θ 600 rpm	θ 300 rpm	PV	AV	YP	n	k
1	24.5	0	61	43	18	30.5	43	0.50	1.902
2	22.05	2.45	65	45	20	32.5	45	0.53	1.651
3	19.6	4.9	75	46	29	37.5	46	0.70	0.585
4	17.5	7.0	41	28	13	20.5	28	0.55	0.907
5	14.7	9.8	40	25	15	20	25	0.68	0.351
6	12.25	12.25	45	32	13	22.5	32	0.49	1.507
7	9.8	14.7	25	12	13	12.5	12	1.06	0.016
8	7.0	17.5	20	12	8	10	12	0.58	0.322
9	4.9	19.6	9	5	4	4.5	5	0.85	0.024
10	2.45	22.05	8	5	3	4	5	0.68	0.072
11	0	24.5	5	2.5	2.5	2.5	2.5	1.00	0.005

Reading taken with viscosifying agent "PAC R" (poly avonic cellulose) additive 0.2g is shown on Table 9

Table 9: Reading with 0.2 g viscosifying agent "PAC- R" (poly avonic cellulose) additive using procedure B

Blend Number	**WYOMIC Clay (g)**	**EMEDE Clay (g)**	**θ 600 rpm**	**θ 300 rpm**	**PV**	**AV**	**YP**	**n**	**K**
1	24.5	0	91	70	21	45.5	49	0.38	6.63
2	22.05	2.45	75	55	20	37.5	35	0.39	6.94
3	19.6	4.9	72	50	22	36	14	0.36	8.37
4	17.5	7.0	60	41	19	30	11	0.55	1.34
5	14.7	9.8	65	50	15	32.5	17.5	0.38	4.74
6	12.25	12.25	60	46	14	30	16	0.38	4.22
7	9.8	14.7	28	19	9	14	5	0.56	0.58
8	7.0	17.5	25	17	8	12.5	4.5	0.56	0.53
9	4.9	19.6	11	7	4	5.5	1.5	0.65	0.12
10	2.45	22.05	20	12	8	10	2	0.74	0.12
11	0	24.5	10	5	5	5	0	1.00	0.01

Table 10 : The Gel Strength after ProceduresA & B

S/N	WYOMIC CLAY	EMEDE CLAY	PAC-R (0.1 g)		PAC-R (0.2 g)	
	(gram)	(gram)	10 sec	10 min	10 sec	10 min
1	24.5	0	36	61	40	63
2	22.05	2.45	32	55	35	75
3	19.6	4.9	40	52	48	76
4	17.5	7.0	6	40	22	44
5	14.7	9.8	4	7	30	52
6	12.25	12.25	15	23	25	55
7	9.8	14.7	2	3	6	21
8	7.0	17.5	3	2.5	5	20
9	4.9	19.6	1	1	0.5	4
10	2.45	22.05	1	1.5	0.5	2
11	0	24.5	0.5	0.5	2	0.5

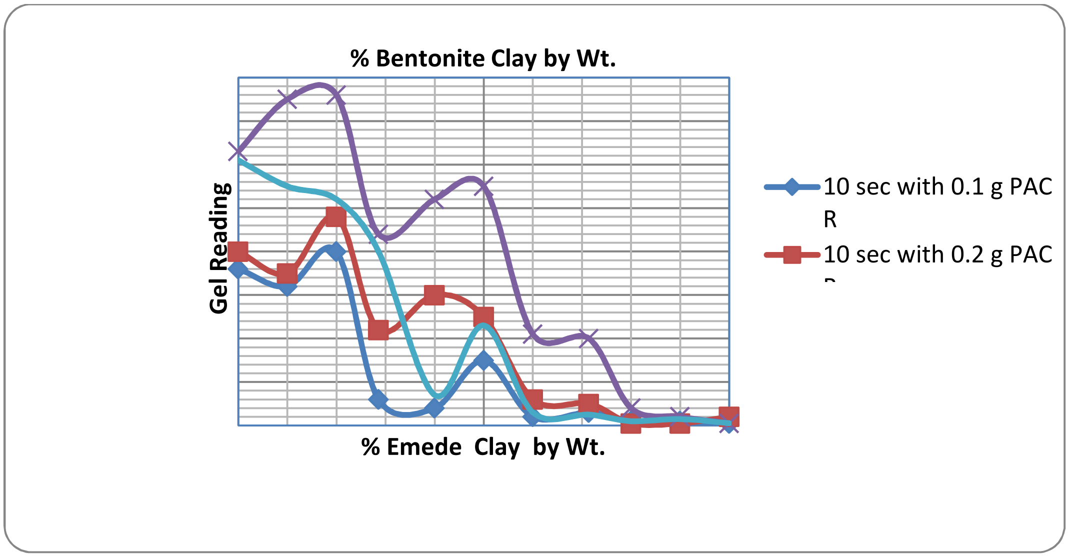

Figure 9: Change in Gel strength with composition.

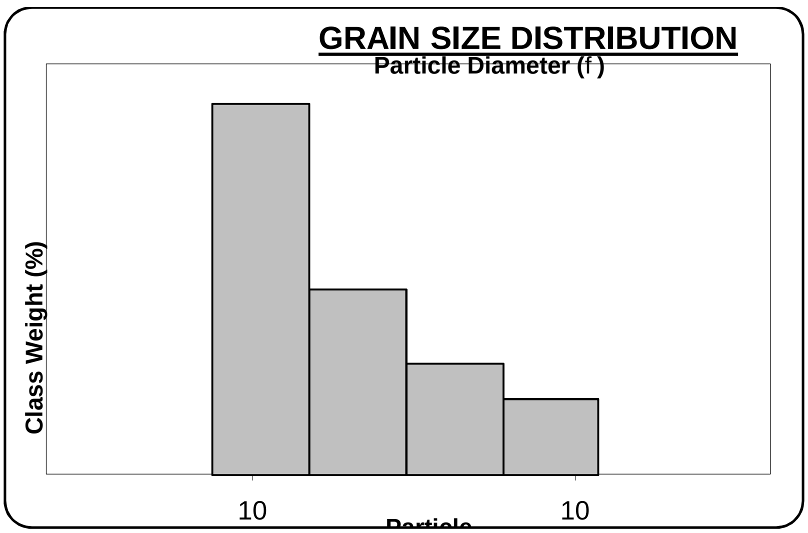

Figure 10: Grain Size Distribution

A plot of the respective gel strength (Figure 9) shows that the mud reacts favourably to the increase in PAC R concentration. From the grain size distribution it was observed that Emede sand consists of unimodal poorly sorted coarse – very fine sand (Figure 10).Analysis was done using the geological software GRADISTAT [7].
The respective percentages of each class are shown in Figure 11. It can be observed from the results that the clay is not a mature clay deposit. The determination of the geologic age was considered beyond the scope of study.

SAMPLE STATISTICS

SAMPLE IDENTITY:	**Emede**	ANALYST & DATE:	P.N.Onwuachi-Iheagwara, 2
SAMPLE TYPE:	Unimodal, Poorly Sorted	TEXTURAL GROUP:	Sand
SEDIMENT NAME:	Poorly Sorted Very Fine Sand		

	μm	ϕ
MODE 1:	112.5	3.237
MODE 2:		
MODE 3:		
D_{10}:	86.15	0.737
MEDIAN or D_{50}:	150.0	2.737
D_{90}:	600.0	3.537
(D_{90} / D_{10}):	6.964	4.799
$(D_{90} - D_{10})$:	513.8	2.800
(D_{75} / D_{25}):	2.828	1.864
$(D_{75} - D_{25})$:	193.9	1.500

GRAIN SIZE DISTRIBUTION			
GRAVEL:	0.0%	COARSE SAND:	11.5%
SAND:	100.0%	MEDIUM SAND:	17.6%
MUD:	0.0%	FINE SAND:	31.6%
		V FINE SAND:	36.8%
V COARSE GRAVEL:	0.0%	V COARSE SILT:	0.0%
COARSE GRAVEL:	0.0%	COARSE SILT:	0.0%
MEDIUM GRAVEL:	0.0%	MEDIUM SILT:	0.0%
FINE GRAVEL:	0.0%	FINE SILT:	0.0%
V FINE GRAVEL:	0.0%	V FINE SILT:	0.0%
V COARSE SAND:	2.4%	CLAY:	0.0%

	METHOD OF MOMENTS			FOLK & WARD METHOD		
	Arithmetic μm	Geometric μm	Logarithmic ϕ	Geometric μm	Logarithmic ϕ	Description
MEAN ($\bar{x}$):	269.0	191.0	2.388	185.5	2.430	Fine Sand
SORTING (σ):	237.1	2.015	1.011	2.119	1.083	Poorly Sorted
SKEWNESS (Sk):	1.718	0.873	-0.873	0.436	-0.436	Very Coarse Skewec
KURTOSIS (K):	4.853	2.504	2.504	0.926	0.926	Mesokurtic

Figure 11: Sample Statistics

6.0 Conclusion

Emede clay from south south-Nigeriawasbeneficiated using PAC-R. The PAC-R was used in two concentrations and the effect of different concentration on the Emede clay was investigated to determine its suitability for use in water-based drilling mud formulation.

The pH ranged from 5 to 9 (Table 3) this is pretty low. An acidic mud is not desirable as there is a possibility of corrosion of down hole equipments; however this can be improved using pH modifiers.

The mud density 8.5-8.6 (Table 5) as compared with 8.65-9.60 is acceptable with the petroleum industry. The density of the drilling fluid is of great importance; as it is used to maintain the pressure between the formation and the borehole. The pressure must be delicately balanced to avoid the dangers of formation damage and kick.

However further beneficiation maybe necessary before the mud is completely acceptable by API standard.

Preliminary investigation suggests that Emede clay has a good potential for use in drilling operations when beneficiated appropriately.

7.0 Acknowledgements

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1. Delta State University, Abraka, Oleh Campus, Nigeria
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