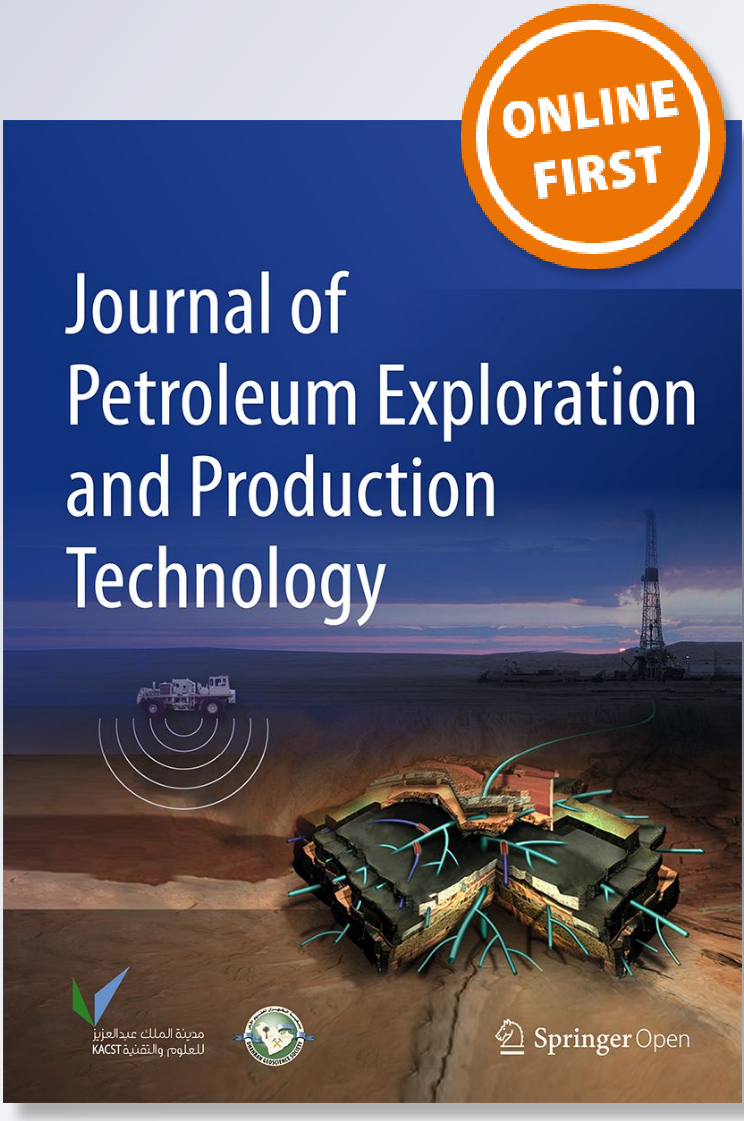
Optimizing aqueous drilling mud system viscosity with green additives

Evelyn Bose Ekeinde, Emmanuel Emeka Okoro, Adewale Dosunmu & Sunny Iyuke

Journal of Petroleum Exploration and Production Technology

ISSN 2190-0558

J Petrol Explor Prod Technol
DOI 10.1007/s13202-018-0481-0



Journal of Petroleum Exploration and Production Technology
https://doi.org/10.1007/s13202-018-0481-0

ORIGINAL PAPER - EXPLORATION ENGINEERING

Optimizing aqueous drilling mud system viscosity with green additives

Evelyn Bose Ekeinde[1] · Emmanuel Emeka Okoro[2] · Adewale Dosunmu[1] · Sunny Iyuke[3]

Received: 24 January 2018 / Accepted: 10 May 2018

Abstract

Non-governmental and governmental agencies are demanding for environmentally friendly mud systems. This increase in environmental awareness has made the drilling mud service companies to re-evaluate some of the chemicals and materials used as additives for mud systems. In this study, some green materials were considered as possible substitutes for PAC R in water-based drilling fluid systems. The rheological properties of four water-based mud systems with typical compositions were studied at 80 and 150 °F. These two temperature ranges were necessary so as to evaluate the effect of temperature on the viscosity, plastic viscosity and yield point properties of these mud systems formulated with these green materials as viscosifier. These green materials were processed to powder form and sieved to their finest particle sizes to reduce amount of solute that will be present in the water-based drilling fluid formed with the materials. The properties of the formulated mud systems were analyzed using API standard. These green materials behaved optimally as viscosifiers for the formulated water-based mud systems under ambient temperature. Also the mud systems behaviour at 150 °F showed a reduction in the flow properties at this high temperature as recorded in the literatures. From the results of the experiment, we can say that Kian (*Averrhoa carambola* L.) has the characteristic of being a substitute for PAC R when beneficiated for water-based drilling fluids.

Keywords Green materials · Water based mud · *Averrhoa carambola* · PAC R

Introduction

The term drilling mud applies to fluids used to keep up well control and transport drill cuttings from the boreholes to the surface. Drilling mud forms an essential part of drilling operations and the factors considered in proper fluid selection include drilling performance, anticipated well condition, safety of personnel, cost, and mud cuttings disposal (Okoro et al. 2015). Drilling muds must be formulated to minimize problems associated with formation damage, well chemistry and other well instabilities. A notable task confronting mud engineers is how to control and stabilize mud properties to optimize drilling operation at lowest cost possible. The literature has shown that a cluster of mud additives are available to treat most of these significant instabilities in the wellbore, but the question will be how cost effective these additives are per foot drilled, after formulation of drilling mud system.

Ibrahim et al. (2017) outlined some of the functions of a drilling fluid and they also mentioned that some of its functions can contribute to formation damage or permeability impairment. They noted that the selection of suitable mud for individual reservoir is critical. Mud additives contain synthetic and natural chemical compounds that help improve their functions during drilling operation; thus, the additives used for this specific drilling mud are also critical because they define the properties of drilling mud. Ghasemi et al. (2017) observed from their study that the size of the additives present in a mud system can influence the plastic viscosity and yielding point. Elkatatny (2017) emphasized the importance of drilling mud rheological properties and their direct effect on drilling operations.

✉ Evelyn Bose Ekeinde
ekens101@yahoo.com

Emmanuel Emeka Okoro
emeka.okoro@covenantuniversity.edu.ng

[1] Petroleum Engineering Department, University of Port Harcourt, Choba, Nigeria

[2] Petroleum Engineering Department, Covenant University, Ota, Nigeria

[3] Chemical Engineering Department, University of the Witwatersrand, Johannesburg, South Africa

Published online: 31 May 2018

Agwu and Akpabio (2018) in their study noted that, an effective, environmental friendly and inexpensive drilling mud additive should be ideal for mud formulation. Wajheeuddin and Hossain (2017) highlighted environmental issues and concerns for some of the chemicals used as additives for conventional drilling fluid system, as reasons why non-governmental and governmental agencies are demanding for environmentally friendly mud system. This increase in environmental awareness has made the drilling mud service companies to re-evaluate some of the chemicals and materials used as additives for mud systems. Wajheeuddin and Hossain (2017) proposed that naturally occurring materials with similar properties as these chemicals should be used. In line with their study and findings, some of the materials used in this present study have these characteristics and are also agro-waste materials.

The viscosity green additives

Guar gum powder

Guar gum is a unique substance derived from the Guar plant, with numerous usages. Primarily, there are two types of Guar gum: food grade Guar gum and Industrial grade Guar gum. For the purpose of this study, the industrial grade Guar gum will be used. During drilling operations, Guar gum functions as an excellent additive for mud systems because of its unique characteristics and properties. These properties include, but are not limited to, loss control agent, viscosifiers and polymer (Chudzikowski 1971; Mudgil et al. 2014).

Xanthan gum

It has also appeared as a highly desirable drilling mud additive that helps in minimizing associated well instabilities. Fundamentally, it is a polysaccharide and a biological polymer product from carbohydrates; and can be produced from xanthomonas campestris in controlled condition (Lopes et al. 2015). Some of the most discrete properties of Xanthan gum, which makes it a drilling mud additive, include its use as a stabilizer, emulsifier (in some cases), suspending agent and a thickener for mud systems (Katzbauer 1998; Luvielmo et al. 2016).

Averrhoa carambola L. (Kian)

Narain et al. (2001) and Thomas et al. (2008) in their study gave a detailed analysis and observations on physical and chemical composition of the material in different maturity stages; and also the fruit physico-chemical analysis. Our interest is on the ripe stage. The seed was dried and grinded to its powder form. The powder form was further sieved with a 212 m size sieve and that was the form used for a QAQC test in the mud laboratory (Fig. 1). The Kian powder acted as a thickener during the test process.

Brachystegia nigerica (Achi)

Brachystegia nigerica (Achi) belongs to the family of leguminosae and the sub family caesalpiniaceae flowering plants. It grows mainly along river banks or swampy areas, though it can be found in well drained soils. Uwaezuoke et al. (2017) in their study listed viscosity and density as vital properties of a mud system; they also identified some green materials that can act as thickener in a mud system. Atuanya and Ibhadode (2011), after characterization of Brachystegia in their study, concluded that it can be used as reinforcement in polymer matrix composites; thus, its fibers can be used as reinforcements in thermoplastic composites.

Detarium microcarpum (OFFOR)

Detarium microcarpum is particularly associated with dry savannah. It grows naturally in forests, flowers throughout the wet season and bears fruits between November and

Fig. 1 *Averrhoa carambola* L. (Kian) fruit and its powdered form

January. It is nutritious, wholesome, and stimulates the appetite. Thickening usually improves the taste of soups, but most important is their nutritional value in foods. In fact, the nutritional value of soups is determined by the thickening agent used. Thickening agents, or thickeners, are substances which, when added to an aqueous mixture, increase its viscosity.

Methodology

These green materials were processed to powder form and sieved to their finest particle sizes to reduce the amount of solute that would be present in the water-based drilling fluid formed with the materials. QAQC analyses were conducted on these green materials before applying them as possible substitutes for other available viscosifying agents. Standard viscosifying agent (PAC R) was also used to formulate water-based mud for proper comparison. The properties of the formulated mud systems were analyzed using API standard.

A total of four water-based mud systems were formulated for the QAQC analysis and the rheological properties analysis. Both the green materials and PAC R mud systems contained the same amount of additives and were exposed to the same temperature and pressure conditions (Table 1).

Results and discussion

Experimental measurements on suitability and compatibility of these green materials as water-based mud fluid viscosifying agent were conducted with respect to API standard. The QAQC test, which is a bench analysis, showed that these materials acted as thickeners and thus, were further used for formulation and mud properties analysis. Their results are presented in Table 2. During formulation, these viscosifiers were applied at different concentrations ranging from 0.5 to 3 ppb; but 2 ppb showed a positive trend in the mud property.

The plastic viscosity (PV) depends mainly on the concentration of solids and the viscosity of the base liquid and the yield point (YP) is a measure of the degree of non-Newtonian shear thinning behavior of the mud system. It can be deduced from Fig. 2 that these green materials behaved optimally as viscosifiers for the formulated water-based mud systems under ambient temperature. In addition, the mud system's behaviour at 150 °F was considered and a reduction in the flow properties were recorded at this increased temperature (Fig. 3). This observation was also recorded by Zhao et al. 2008, Makinde et al. (2011) and Amani and Al-Jubouri (2012) for different viscosifiers used in their studies. Kian and OFFOR green materials were within the API standard at temperature of 150 °F.

Table 1 The water-based mud systems formulation composition

	PAC R	OFFOR	Achi	Kian
Water	322	322	322	322
Soda ash	0.25	0.25	0.25	0.25
Caustic soda	0.25	0.25	0.25	0.25
KCL	25	25	25	25
PAC L	1	1	1	1
Barite	77	77	77	77

Table 2 Rheological analysis for the water-based mud using the viscosifiers

Rheological properties (RPM)	API standard	PAC R	Achi	OFFOR	Kian
600		74	40	61	68
300		48	25	39	44
200		36	19	27	32
100		22	12	18	20
6		3	2	2	3
3		2	1	1	2
10 s (lb/100 ft^2)	2–8	3	1	1	1
PV	12–25	26	15	22	24
YP	10–20	22	10	17	20

Conclusion

In this study, we looked at the suitability of some selected green materials as viscosifiers and the possible effect of temperature on the rheological properties of water-based mud formulated with them. The mud system properties of these green materials were compared with PAC R which is

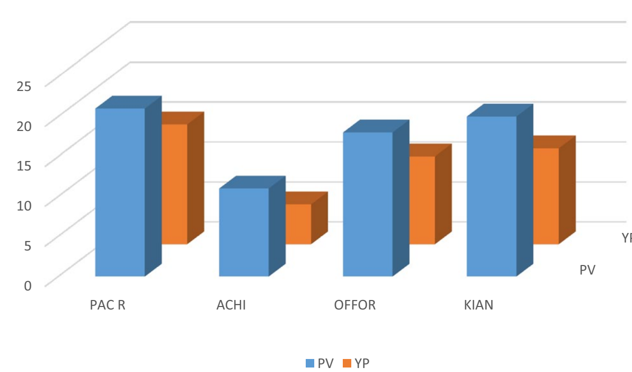


Fig. 2 Flow properties of the water based mud for each viscosifiers at 80 °F

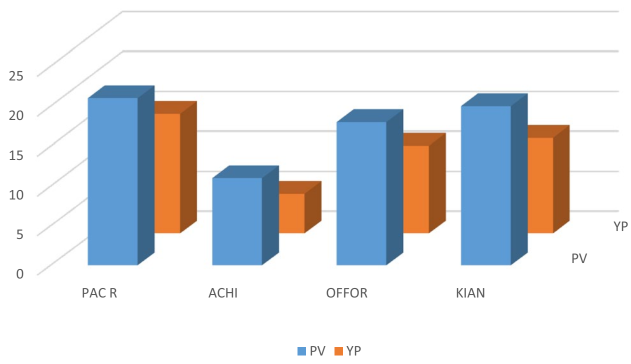


Fig. 3 Flow properties of the water based mud for each viscosifier at 120 °F

mostly used in the industry for water-based mud systems. Furthermore, the temperatures at which these green materials can be affected were determined. From the results of the experiment, we can say that Kian (*Averrhoa carambola* L.) has the characteristic of being a substitute for PAC R when beneficiated for water-based drilling fluids.

References

Agwu OE, Akpabio JU (2018) Using agro-waste materials as possible filter loss control agents in drilling muds: a review. J Pet Sci Eng 163:185–198

Amani M, Al-Jubouri M (2012) The effect of high pressures and high temperatures on the properties of water based drilling fluids. Energy Sci Technol 4(1):27–33. https://doi.org/10.3968/j.est.1923847920120401.256

Atuanya CU, Ibhadode AOA (2011) Characterization of Okhuen (*Brachystegia nigerica*) wood as a potential reinforcement for polymer composites. Int J Eng Technol IJET-IJENS 11(04):52–59

Chudzikowski RJ (1971) Guar gum and its applications. J Soc Cosmet Chem 22:43–60

Elkatatny S (2017) Real-time prediction of rheological parameters of KCl water-based drilling fluid using artificial neural network. Arab J Sci Eng 42:1655–1665

Ghasemi N, Mirzaee M, Aghayari R, Maddah H (2017) Investigating created properties of nanoparticles based drilling mud. Heat Mass Transf 54(5):1381–1393

Ibrahim DS, Sami NA, Balasubramanian N (2017) Effect of barite and gas oil drilling fluid additives on the reservoir rock characteristics. J Pet Explor Prod Technol 7(1):281–292

Katzbauer B (1998) Properties and applications of xanthan gum. Polym Degrad Stab 59(1–3):81–84

Lopes BM, Lessa VL, Silva BM, La Cerda LG (2015) Xanthan gum: properties, production conditions, quality and economic perspective. J Food Nutr Res 54(3):185–194

Luvielmo MM, Borges CD, de Oliveira Toyama D, Vendruscolo CT, Scamparini ARP (2016) Structure of xanthan gum and cell ultrastructure at different times of alkali stress. Braz J Microbiol 47:102–109

Makinde FA, Adejumo AD, Ako CT, Efeovbokhan VE (2011) Modelling the effects of temperature and aging time on the rheological properties of drilling fluids. Pet Coal 53(3):167–182

Mudgil D, Barak S, Khatkar BS (2014) Guar gum: processing, properties and food applications—a review. J Food Sci Technol 51(3):409–418

Narain N, Bora PS, Holschuh HJ, Da MA, Vasconcelos S (2001) Physical and chemical composition of carambola (Kian) fruit (*Averrhoa carambola* L.) at three stages of maturity. Cienc Technol Aliment 3(3):144–148

Okoro EE, Dosunmu A, Oriji B, Iyuke S (2015) Impact of reversible invert emulsion drilling fluid rheology on productivity. SPE-178308-MS, Nigerian Annual Technical Conference and Exhibition

Thomas S, Patil DA, Patil AG, Chandra N (2008) Pharmacognostic evaluation and physiochemical analysis of *Averrhoa carambola* L. fruit. J Herb Med Toxicol 2(2):51–54

Uwaezuoke N, Igwilo KC, Onwukwe SI, Obah B (2017) Effects of temperature on *Mucuna solannie* water-based mud properties. Int J Adv Eng Res Sci (IJAERS). https://doi.org/10.22161/ijaers.4.1.13

Wajheeuddin M, Hossain ME (2017) Development of an environmentally-friendly water-based mud system using natural materials. Arab J Sci Eng. https://doi.org/10.1007/s13369-017-2583-2

Zhao S-Y, Yan J-N, Shu Y, Zhang H-X (2008) Rheological properties of oil-based drilling fluids at high temperature and high pressure. J Central South Univ Technol 15(Supplement 1):457–461