




# An ecological water-based drilling mud (WBM) with low cost: substitution of polymers by wood wastes

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## Abstract

An ecologically friendly water-based drilling mud (WBM) was designed by using wood wastes (WP: wood powder) in order to substitute the organic polymers which are very expensive and often make the higher cost of the oil well drilling. This present work is dedicated on studying the rheological behavior and main rheological properties of WBM containing the wood powder at different contents and sizes by substitution of usually used polymers. The effect of wood powder on the drilling fluid filtrate was also analyzed. The drilling fluid that was developed has better rheological properties and fluid loss control which are required for a good functioning of oil well drilling. By a total substitution of polymers, the wood powder (300  $\mu\text{m}$  at 850  $\text{kg}/\text{m}^3$ ) can be used as a filtrate reducer of mud because the WBM filtrate obtained exhibits a minimum and having requested values for such formation.

**Keywords** Wood wastes · Drilling mud · Organic polymer · Yield point · Viscosity · Rheological behavior

## Introduction

The use of polymers such as cellulose derivatives (Bentriou et al. 2014; Yang et al. 2007; Kok and Alikaya 2005; Leliang and Guijuan 2003; Ling et al. 1999; Hughes et al. 1993), biopolymers (Jun et al. 2001; Xie et Lecourtier 1992; Navarrete et al. 2001), and guar gum (Bentriou et al. 2014; Mahto and Sharma 2004; Sharma et Mahto 2006) became indispensable in water-based drilling fluids to replace the oil-based mud for environmental considerations. Many studies were carried using different polymers in formulation of water-based drilling muds. These studies have shown the efficiencies of some polymers on the rheological and physicochemical performance of fluid. Comparing between the different polymers, the most used principally as a filtrate

reducer is the cellulose derivative because it is biodegradable and compatible with other components of drilling mud. Carboxy-methyl-cellulose (CMC) is produced by cellulose reaction obtained from wood pulp or cotton fiber with chloroacetic acid and NaOH. Among the polymers most used as a fluid loss reducer of WBM is that of polyanionic cellulose (PAC) because it has the power to increase the viscosity of the suspension. The latter is also regarded as viscosity modifier of the mud system (Safi et al. 2016; Bruton et al. 2000). Two types of polymer PAC are available: the high viscosity and the low viscosity. Both of them have the same degree of fluid loss control, but different degrees of viscosity (Safi et al. 2016; Baba Hamed and Belhadri 2009; Plank 1992).

However, research tends to use or valorize some wastes to minimize the cost of drilling operation. Today, environmental constraints require us to seek an alternative component for drilling fluids that can replace the polymers without disrupting rheological characteristics of drilling fluids. Among wastes that can be used as component of drilling fluids is that the wood wastes. According to the literature review, it is noted that no studies have been performed on the use of wood powder or wood dust in formulation of drilling fluids. The wood sawdust designates all wood waste obtained from the lumber and produced during machining operations performed on the raw material (wood). The resulting chips of

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manufacture can be well recovered and recycled to the field of construction (Kim and Song 2014; Kim et al. 2013; Jungmeier et al. 2003). Many researches have been conducted using wood sawdust in different fields and different forms (Daoui et al. 2015; Djoudi et al. 2012; Briens et al. 2008; Turgut and Algin 2007; Garrote et al. 2003). However, few study research has been conducted using wood wastes as a filtration control and density additives in WBM (Adebayo and Precious 2012; Anawe Paul et al. 2015). In this work, the authors found that an optimum weight percentage of sawdust was obtained, and it is recommended for application of the different size grades of the sawdust if they are to serve as weight control additive. The contents founds are 5.9 wt% sawdust for 0.5 mm, 3.8 wt% sawdust for 1.0 mm, and 3.5 wt% for greater than 1.0 mm sawdust. The authors were observed also that for weight percentage higher than 5% for sawdust greater than 1.0 mm, the mud cake was very unstable. The reuse of different wood wastes was also the subject of numerous studies but in another material not drilling fluids (Daoui et al. 2015; Djoudi et al. 2012). The structural properties of wood and the presence of longitudinal cavity are of interest in the treatment of wastewater, by fixing various undesirable elements on the walls of the material. Sawdust, natural or chemically treated, from different tree species, has been the subject of several studies on their ability to fix different pollutants in wastewater. However, recovery and usage of sawdust or wood powder as constituent in the drilling fluids need to be studied. For this, our study will focus on the use and recycling of wood powder by polymer substitution in WBM.

## Experimental study

### Materials used

To conduct this study, the chosen water-based muds are those currently used for drilling oil wells in Algeria. Polymer products and materials used are bentonite, caustic soda, soda ash, potassium chloride, cellulose polyanionic (PAC\_ul and PAC\_R), carboxy-methyl-cellulose (CMC), and xanthane (XCD). Table 1 gives the composition and rheological properties of water-based mud used in this work. Those muds were prepared using API equipment (API RP 13B-1, 2003).

### Using the wood powder

In order to evaluate the use of wood powder in WBM, the Aleppo pine wood was used in this work at three different fractions and dosages. The coupons of Aleppo pine were recovered as waste from wood manufacture. The wood powder was introduced by substitution, first of PAC\_ul and

**Table 1** Mud formulation for a density  $d=1.05$

Products	Dosage (kg/m <sup>3</sup> )	Rheological properties		
Caustic soda	1	Read speed	PV cps	
Soda ash	0.7	600	54	16
Bentonite	20	300	38	AV cps
PAC-ul	5.7	200	33	27
PAC-R	0.7	100	28	Yvlbs/100ft <sup>2</sup>
CMC LV	6	6	22	22
XCD	0.7	3	20	
KCL	40	Gels 10"/10'	21/25	
Defoamer	0.5	Filtrate cc/30 mn	6	

PV plastic viscosity; AV apparent viscosity; and Yv yield value or yield point

CMC, then secondly by substitution the XCD and PAC\_R. This procedure was chosen to know the role played by the waste.

The microscopic structure of Aleppo pine used in this study, obtained by scanning electron microscopy (SEM) and X-ray diffraction (XRD), is given in Fig. 1. According to the figure, this wood powder has a crystalline phase and an amorphous phase. It is noted that many studies have confirmed the structure of wood of Aleppo pine, because this wood type is composed of cellulose, hemi cellulose, lignin, and some trace minerals (Popescu and Vasile 2010; Popescu et al. 2011; Sugiyama et al. 1991). These minerals are generally in the silica cristobalite form (see Fig. 1a).

### Test methods

Rheological behavior and parameters were determined by rheological tests. The rheological tests were conducted using a rheometer fann 35 at variable speed (3–600 rpm). A viscometer giving values in cP or in mPa s by using the formulas known from API recommended practice for field testing drilling fluids, and they are equations usually used on the site and also used by many authors (Safi et al. 2016; Bruton et al. 2000). API filtrate and gel 0/10 (3 rpm dial reading after mixing and after 10 min) are determined with using API recommendations (API RP 13B-1, 2003).

## Results and discussions

### PAC and CMC substitution by wood powder

#### Rheological behavior

Figures 2, 3, 4, 5 give rheological behavior of studied WBMs with PAC and CMC substitution by WP at different contents

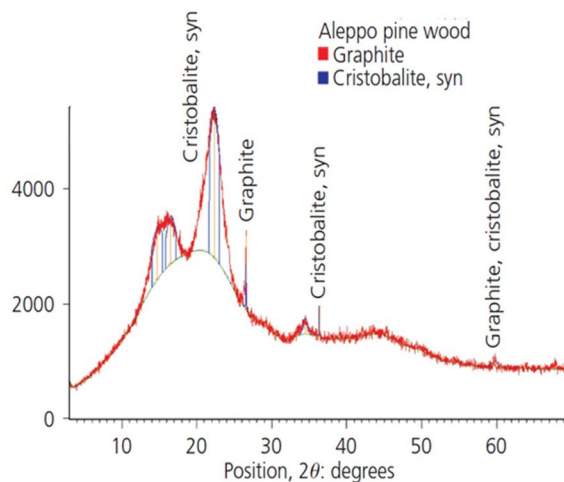
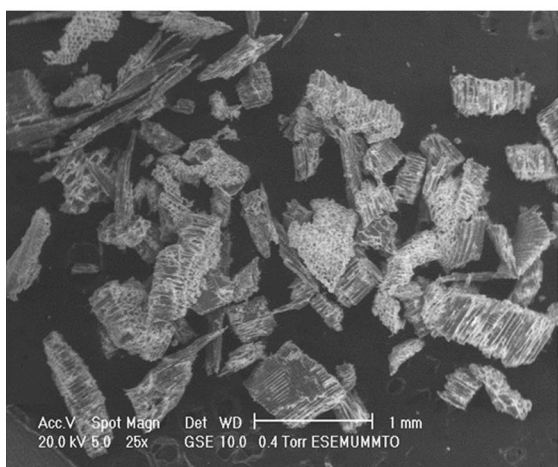


Fig. 1 Wood powder used (wastes of Aleppo pine). a SEM, b XRD

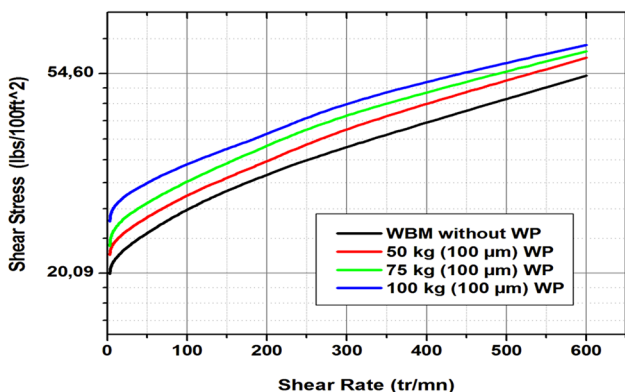


Fig. 2 PAC<sub>ul</sub> and CMC substituted by wood powder (WP at size = 100 µm) at different contents

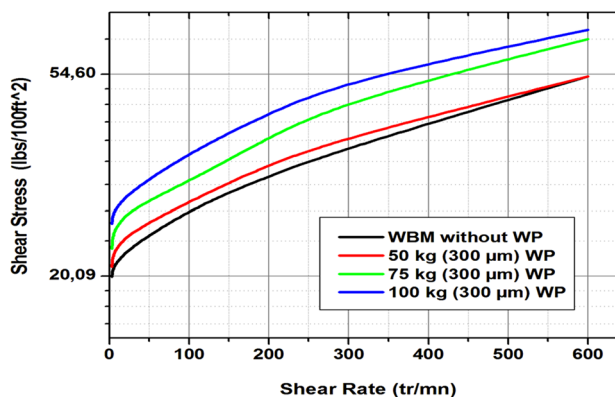


Fig. 4 PAC<sub>ul</sub> and CMC substituted by wood powder (WP at size = 300 µm) at different contents

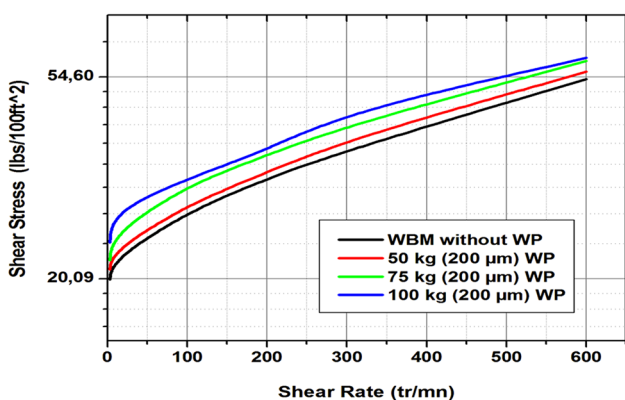


Fig. 3 PAC<sub>ul</sub> and CMC substituted by wood powder (WP at size = 200 µm) at different contents

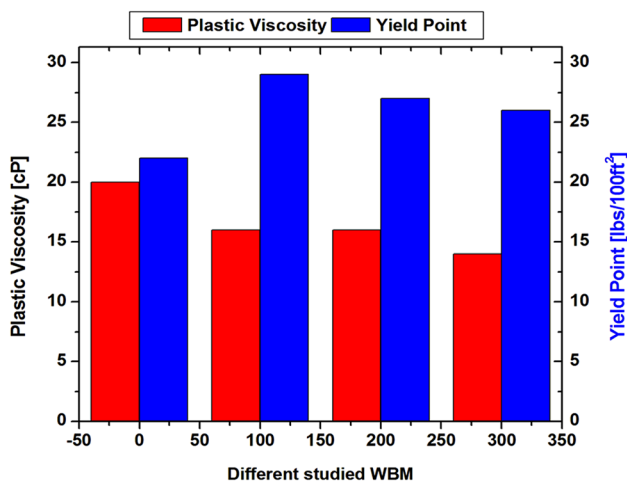


Fig. 5 Main rheological parameters of studied muds: PAC<sub>ul</sub> and CMC substitution

and particle sizes. According to obtained rheograms, all suspensions show non-Newtonian flow. However, the behavior of these suspensions can be identified by using rheological

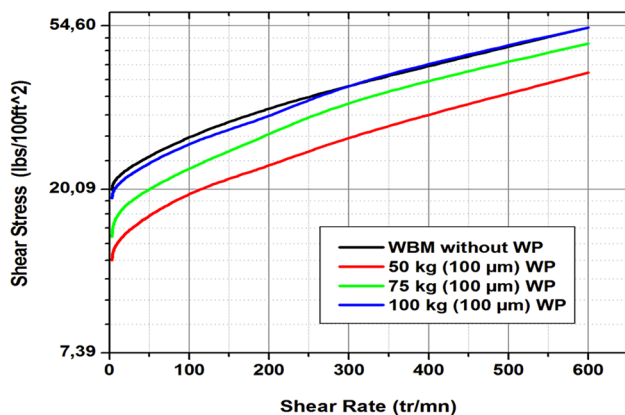
models known. Indeed, several studies have found that the behavior of these mud types follows the Herschel–Bulkely model. In this case, all studied muds show a non-Newtonian flow because the suspensions represent a flow threshold that means they have a non-Newtonian behavior. According to several researchers (Safi et al. 2016; Maallem et al. 2013; Kayacier and dogan, 2006), they have found that the behavior of these types of mud follows the model of Herschel–Bulkely. Regardless of the dosage and size of wood particles, rheological behavior of studied WBM is same and has Herschel–Bulkely behavior.

Generally, shear stresses for all the samples tend to increase as WP content increased. Also, effect of WP additive produced the decrease in viscosity at 100 kg/L. It was noted that with substitution of PAC and CMC per 100 kg/L of PW, the viscosity increased by 29% and then stabilized above 200 and 300 kg/L. However, it is noted that yield value has fallen beyond these dosages. This proves that the wood powder has a viscosifying effect and can be used by replacing the viscosifier polymers.

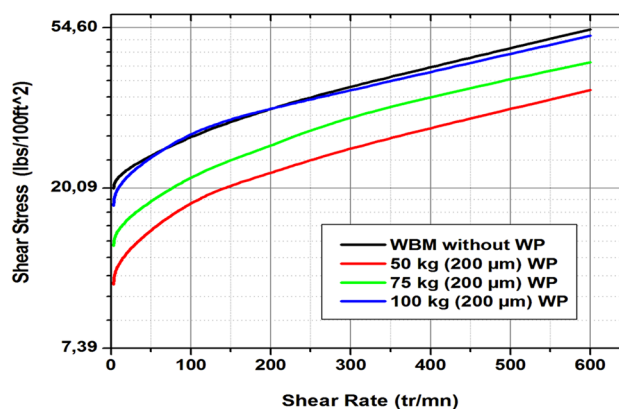
### XCD and PAC\_R substitution by wood powder

#### Rheological behavior

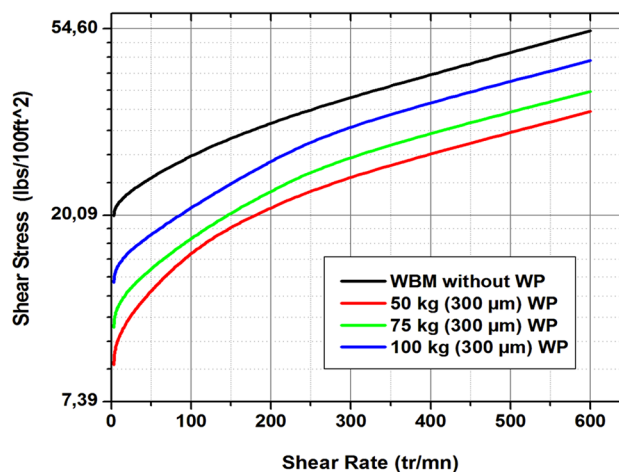
Rheological behavior of WBMs with XCD and PAC\_R substituted by WP at different contents and particle sizes is given in Figs. 6, 7, 8, 9. As the last results and according to



**Fig. 6** XCD and PAC\_R substituted by wood powder (WP at size = 100  $\mu\text{m}$ ) at different contents



**Fig. 7** XCD and PAC\_R substituted by wood powder (WP at size = 200  $\mu\text{m}$ ) at different contents



**Fig. 8** XCD and PAC\_R substituted by wood powder (WP at size = 300  $\mu\text{m}$ ) at different contents

obtained rheograms, all suspensions show non-Newtonian flow, and the behavior of these suspensions can be identified by using rheological models known. Some observations concerning the rheological behavior have been reported. However, the muds show also a non-Newtonian flow described by the Herschel–Bulkely model but with an other yield value (Safi et al. 2016; Maallem et al. 2013).

It can be seen that the shear stress increases with the increase in the WP content in all samples for different sizes;

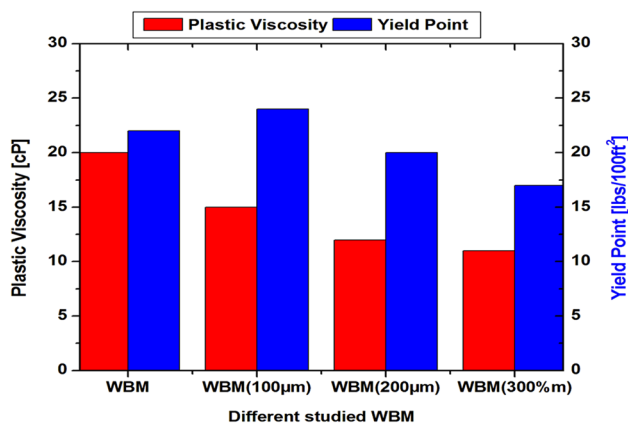


Fig. 9 Main rheological parameters of studied muds: XCD and PAC\_R substitution

for that at 100 and 200 µm, it is superimposed on that without WP, and for that at 300 µm, it is much lower than that without WP. Meanwhile, the addition of the WP causes a decrease in plastic viscosity and that apparent such as the particle size of the WP increase, the decrease in plastic viscosity is greater for particles which have a size of 100 µm and it stabilizes at sizes of 200 and 300 µm. The apparent viscosity is constant around 20 cP for particles which have sizes from 0 to 100 µm and decreases considerably for sizes of 200 to 300 µm. We can note also that the value of the yield increases for an addition of the WP which has sizes of 100 µm and then it decreases for larger sizes.

The quantity of filtrate containing WBM samples where XCD and PAC-R were substituted by WP which has size of 100 µm decreases according to the quantity of WP added, from 6 cc/30 mn for a WBM without WP up to 3 cc/30 min for a WBM which has 100 kg/mm<sup>3</sup> of WP, while the filtrate quantity for WBM samples where PAC-ul and CMC were substituted by WP for same particle size (100 µm) was reduced from 17 to 5 cc/30 mn. Compared to muds where XCD and PAC-R have been substituted by WP for the same size, mud filtrate has decreased as function as the quantity of WP added from 18 cc for WBM samples which contain 50 kg/mm<sup>3</sup> to 5 cc/30 mn for the WBMs containing 100 kg/mm<sup>3</sup> (Fig. 10).

By comparing, the filtrate quantity obtained for different sizes of WP is found that for the substitution of XCD and PAC-R by WP, it is the same for all sizes, whereas for the

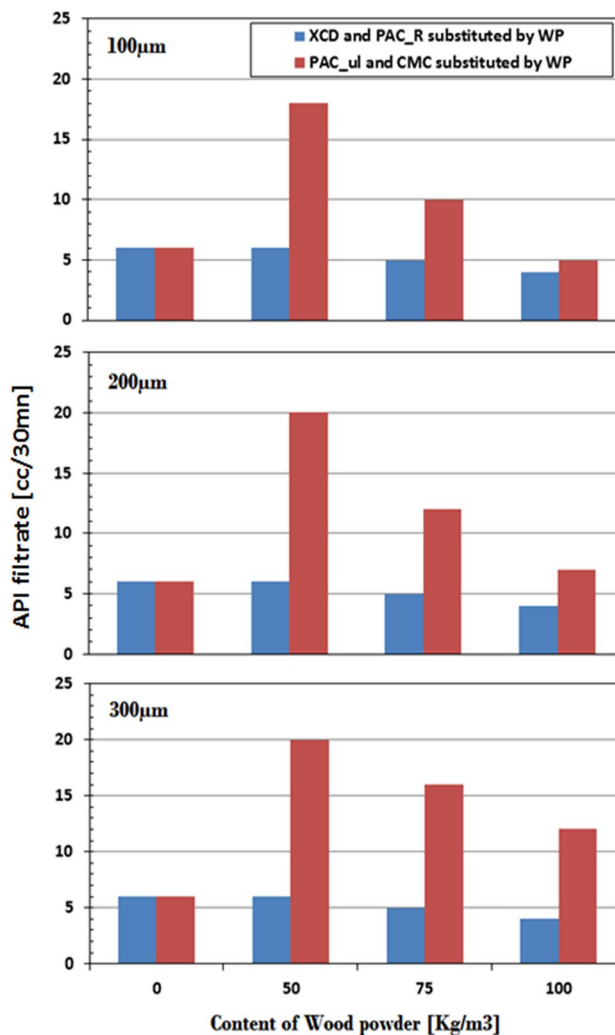


Fig. 10 Mud filtrate of studied muds at different polymer substitution and wood sizes

substitution of PAC-ul and CMC by WP, it is minimal for the sizes of 100 µm and increases with increase in sizes of WP.

As an example to compared the cost price of a WBM containing WP (by 100% substitution of all polymers used) with that currently used mud for drilling oil wells in Algeria. Table 2 summarizes the comparison between a WBM containing imported polymers and that made from wood coupons. This table gives the main characteristics of WBM

**Table 2** Rheological characteristics, API filtrate, and cost price of water-based muds

	Products	Dosage (kg/m <sup>3</sup> )	Rheological characteristics and API filtrate				Cost price/m <sup>3</sup>
			Apparent viscosity (cP)	Plastic viscosity (cP)	Yv (lbs/100ft <sup>2</sup> )	API filtration (cc/30mm)	
WBM with wood powder	Caustic soda	1	10	35	30	8	< 10\$
	Soda ash	1					
	Bentonite	80					
	Wood 300 μm	850					
	–						
	–						
WBM	Caustic soda	1	16	27	22	6	> 50\$
	Soda ash	0,7					
	Bentonite	20					
	PAC-ul	5,7					
	PAC-R	0					
	CMC LV	6					
	XCD	0					
	KCL	40					
	Defoamer	0,5					

and the cost price. It is noted clearly that the wood wastes can be used at least as viscosifier agent or filtrate agent for drilling mud without disturbing the main rheological properties of mud.

## Conclusion

In the present work, rheological and physic measurements have been used to characterize WBM was designed by using wood wastes in order to substitute the organic polymers which are very expensive and often make the higher cost of the oil well drilling. It can be concluded from obtaining results that WBM with WP has better rheological properties and fluid loss control which are required for drilling. It was founded that by a total substitution of polymers, the WP can be used (300 μm at 850 kg/mm<sup>3</sup>) as a filtrate reducer of mud because the WBM filtrate obtained exhibits a minimum and having requested values for such formation. According to the comparison of the cost price of a WBM containing wood wastes (by 100% substitution of all polymers used) with that currently used for drilling oil wells in Algeria, it appears that the wood wastes can be used at least as viscosifier agent or filtrate agent for drilling mud without disturbing the main rheological properties of mud.

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