

Laboratory Study of Environmental Friendly Drilling Fluid Additive to be Exploited as a Multifunctional Bio-enhancer Additive in Water-Based Drilling Fluid

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Abstract

Conventional chemical additives used in controlling drilling fluid properties have severe drawbacks on the environment. The commercially available additives are non-biodegradable materials and have negative impacts when released to the environment. Thus, there is a great need for new environmental friendly biodegradable drilling fluid additives that can help to control the drilling fluid properties and improve their effectiveness with the least effects on the environment and the workers' health.

The effects of adding varying concentrations of Mandarin Peels Powder (MPP) to water-based mud were measured using standard API drilling fluids testing methods such as rheometer/viscometer, pH meter and temperature, filter press, mud balance, various chemical titrations, and resistivity device during static phases. All tests results were minutely recorded to recognize the impact of MPP additive on the drilling fluid properties.

The results showed that MPP reduced alkalinity (pH) by 20%, 23%, 30%, and 32% at 1% (6 gm), 2% (12 gm), 3% (18 gm), and 4% (24 gm) of MPP, respectively; while minimized the filtration volume (cc/30min) by 44%, 52%, 64%, and 68% at 1% , 2% , 3%, and 4% of MPP, respectively. In addition, the filter cake was improved compared to the reference mud. Moreover, the two viscosity components were increased by 50%, 243%, 443%, and 800% at 1%, 2%, 3%, and 4% of MPP for the plastic viscosity (PV), respectively; and by 22%, 55%, 200%, and 418% at 1%, 2% , 3%, and 4% of MPP for the yield point (YP), respectively. However, both types of gel strength were slightly reduced at 1% and 2% of MPP; while MPP had no effect on the gel strength at 3%, and it resulted in a large increase in the initial and final gel strength at 4% as compared to the reference mud. Furthermore, MPP had a minor impact on MW at 1% and 2%, and it had a moderate effect at 3% and 4% due to foaming. Lastly, other properties such as salinity, calcium content, and resistivity were negligibly affected by MPP.

This makes MPP an effective material to be used as a pH reducer, a viscosity modifier, and as an excellent filtration loss control agent. Also, the lab outcomes revealed that MPP can be used to stop the partial losses at 3% (18 gm) and 4% (24 gm) concentrations. Thus, MPP has the potential to be utilized as

biodegradable drilling fluid additive replacing other chemical additives that have usually been used for the same purposes.

This work can serve as a practical guide for minimizing the cost of the drilling fluid and reducing the amount of non-biodegradable waste disposed to the environment.

Background

Drilling fluid consists of a base fluid and various solid and soluble additives that perform a specific function to allow good drilling performance. The performance of drilling fluid affects the overall drilling efficiency. Therefore, the base fluid and additives are carefully selected to fulfill the formation requirements, hydraulic considerations, and hole cleaning efficiency. The factors that guide the selection of base fluid and the additives are complex and well discussed (Okorie, 2009). Environmental considerations led to an increase in the interest of using conventional water-based drilling fluid over oil-based drilling fluid due to the high toxicity of the later especially in environmentally sensitive locations. However, many of the commercially available drilling fluid additives fall under the category of non-biodegradable materials, and the higher focus on economic and performance with little or no attention to the environment has led to the use of toxic chemical additives in the formulation of conventional water-based systems. These additives include; sodium hydroxide, potassium chloride, potassium sulfate, chromium-containing thinners and fluid loss additives etc., have an overall negative environmental impact and are very expensive (Amanullah, 2007).

Today, there is an increase in the global concerns for the protection of the environment from the detrimental effect of chemical and non-biodegradable materials. These concerns drive the industry towards drilling fluid optimization techniques to develop safer and environmental friendly formulations. Strict environmental guidelines set by the environmental protection agencies on the discharge of water effluent to the sea and the disposal of drill cuttings have now motivated researchers to develop cost-effective biodegradable additives that will deliver both good performance and reduce environmental impacts. Recent research efforts have examined the applicability of natural biodegradable waste as drilling fluid additives in order to reduce waste disposal and the toxicity to the environment (Amadi et al., 2018).

One of the studies is the use of rice husk as an environmental friendly filtration control additive that has been conducted by Okon et al. (2014). The result of this study showed that 20 ppb concentration of risk husk was able to reduce fluid loss by 65% when compared to the performance of 10 ppb of Carboxymethyl Cellulose (CMC). On the other hand, the high concentration of rice husk might pose a risk to delicate Measurement While Drilling (MWD) tools and might result in an undesirable effect on the plastic viscosity. This finding points out the importance of optimizing the concentration of rice husk. Iheagwara (2015) in his study showed that banana peel exhibits an alkaline property on drilling mud as conventional caustic soda. Similarly, Adebawale and Raji (2015) examined the use of Banana Peel Ash (BPA) as a substitute additive for NaOH to enhance the pH of the drilling fluid and control corrosion. The study revealed a significant enhancement in pH from BPA. However, comparison of improvement from the same concentration of BPA and NaOH showed an improvement in pH by 12% and 14%, respectively. In addition, corncob and sugar cane were found to have the potential to be used as viscosifying agents. These additives showed an improvement in plastic viscosity but negatively affected the yield point and gel strength by reducing both values when the concentration was increased from 6 to 10 ppb (Iranwan et al., 2009).

Other materials were also tested to investigate their ability to enhance the rheological and filtration properties of water-based mud, these materials are cellulose from corncob (Nmeghu et al., 2014), cashew and mango leaves extracts by Omotoma et al. (2014), and potato starch extracted from potato tubers by Nyeche et al. (2015). The cellulose from corncob was efficient in reducing fluid loss compared to Polyanionic Cellulose (PAC) and the cashew and mango leaves extracts improved the rheological characteristics of the mud, while the potato starch extracted from potato tubers affected the rheological and filtration properties negatively.

In this study, the applicability of utilizing Mandarin Peels Powder (MPP) (a food waste product generated by the food industry) as an eco-friendly drilling fluid additive to improve the rheological and the filtration properties of drilling fluid is presented.

Preparation of the Mandarin Peels Powder (MPP)

The aim of this section is to explain the procedure of preparation of Mandarin Peels Powder (MPP). Initially, the raw waste material was collected at home as shown in **Figure A.1** (Appendix A). Then, it was chopped into very small pieces in order to accelerate the drying process and get rid of moisture rapidly as shown in **Figure A.2** (Appendix A); while **Figure A.3** (Appendix A) shows the dried small pieces of MPP. The small pieces of MPP were placed in an oven at 90-95°C (195-204 °F) for three hours. After that, they were left in a dry space for 10 days. Finally, to guarantee the entire drying process, MPP was placed in an oven again at 90-95°C (195-204 °F) until the material was entirely oxidized. Once dried, MPP additive was ground into a very fine powder using the food processor.

Figure A.4 and **A.5** (Appendix A) illustrate the fine powder of the Mandarin Peels and the food processor, respectively; while **Figure A.6** (Appendix A) will demonstrate the workflow preparation of MPP additive as a powder.

Mud Sample Preparation and Laboratory Measurements

First of all, the reference mud (RM) was prepared to be used as the base point for various concentrations of MPP. The type of reference mud was spud mud (Fresh Water Bentonite), and it consisted of the additives shown in **Table A.1** (Appendix A) after converting from the field to lab units.

Four test samples of drilling fluid were developed by mixing 1% concentration (6 gm) of MPP, then further experiments to investigate the effect of increasing the concentration of the MPP additive from 2% (12 gm) to 3% (18 gm), and 4% (24 gm) were evaluated to minutely understand the impact of concentration variation on the reference mud.

Standard API drilling fluids testing methods such as rheometer/viscometer, pH meter and temperature, filter press, mud balance, various chemical titrations, resistivity device, and retort kit during static phases were utilized in order to evaluate the effectiveness of various concentrations of MPP on water-based drilling fluid. The readings obtained from the experimental work were presented in details for the reference mud and of various concentrations of MPP for all the physical and chemical properties of the drilling mud as shown in **Table A.2** (Appendix A).

Discussion

Based on **Table A.2** (Appendix A), it can be clearly seen that Mandarin Peels Powder (MPP) is a multifunctional bio-enhancer additive, with significant improvement of the rheological and filtration properties of water-based mud. Starting with the mud weight (MW), the MPP had a minor effect at 1% and 2% concentrations and a moderate impact at 3% and 4% concentrations on MW. The reason behind the decrease in MW was foaming and not MPP itself, suggesting using anti-foam additive as pre-treatment or post-treatment to prevent or at least minimize the foaming influence on MW. **Figure A.7** (Appendix A) illustrates the impact of various concentrations of MPP on MW.

For the rheological properties, MPP significantly resulted in increasing PV and YP, especially at 3% and 4% concentrations, suggesting its applicability to be utilized to control the partial losses at 3% and 4% concentrations due to the high marsh funnel viscosity (≈ 100 sec), MPP generated an excellent behavior for the gel strength as shown in **Figure A.8** (Appendix A).

Standard API filter press was used to evaluate the effectiveness of MPP as an environmental friendly filtration control agent. The fluid loss was measured at 7.5 minutes and 30 minutes, and the results showed a tremendous enhancement, and particularly at 3% and 4% concentrations as shown in **Figure A.9** (Appendix A). In addition, the filter cake thickness (mm) was minimized as shown in **Figure A.10** (Appendix A).

The results showed that MPP had the potential to be used as pH reducer, especially when drilling through cement since MPP can reduce the pH effectively. **Figure A.11** (Appendix A) shows the impact of MPP additive on alkalinity.

Additionally, other properties such as salinity (NaCl), calcium content (Ca⁺⁺), and resistivity were negligibly affected by MPP as shown in **Table A.2**. For instance, the results demonstrated that Ca⁺⁺ was reduced from 40 (mg/l) to 4 (mg/l) for all concentrations, and it can be seen that MPP had the potential to reduce pH and precipitate Ca⁺⁺. Hence, it is practically applicable to examine the MPP feasibility in penetrating the cement.

Conclusion

Based on the obtained experimental results, it can be deduced that Mandarin Peels Powder (MPP) additives moderately reduced the mud weight at 3% and 4% concentrations due to foaming; however, the plastic viscosity and yield point were tremendously increased compared to the reference mud, particularly at 3% and 4% concentrations; while the gel strength was negligibly reduced at 1% and 2% concentrations, steady at 3% concentration, and significantly maximized at 4% concentration as compared to the reference mud. In addition, the filtration specifications were enormously improved compared to the reference mud, especially at 3% and 4% concentrations. Moreover, MPP showed that it had a minor effect on the salinity, calcium content, and the mud resistivity.

It was deduced that MPP can be utilized as an environmental friendly alternative additive to increase plastic viscosity, yield point, and enhance the initial and final gel strengths for the drilling mud. Additionally, it can be used as a filtration control agent at 1% and 2% concentrations, and as a high viscosity patch to stop the partial losses at 3% and 4% concentrations.

Lastly, the performance of MPP needs to be examined at aging conditions and at elevated temperatures and pressures alongside other commonly used conventional chemical materials to guarantee their applicability to be utilized in the field.

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Appendix A

Table A.1. The Composition of Spud Mud (Reference Mud)

Material	Amount
Water	600 cc
NaOH	0.6 gm
Bentonite	36 gm

Table A.2. Effect of Variation in the Concentration of Mandarin Peels Powder (MPP) on the Properties of Water-Based Mud

Property	RM	1% MPP	2 % MPP	3 % MPP	4 % MPP
Mud Density, (ppg)	8.6	8.4	8.2	7.9	7.9
PV, (cp)	7	14	24	38	63
YP, (Ib/100ft ²)	11	14	17	33	57
Initial Gel Strength, (Ib/100ft ²)	12	10	10	12	24
Final Gel Strength, (Ib/100ft ²)	17	14	14	17	28
PH	10	8	7.7	7	6.8
Mud Resistivity, (ohms-mt)	7	5.8	5.2	5	4.8
Mud Temperature, (°F)	73	76	76	76	74
Mud NaCl Concentration, (ppm) (nomograph)	750	900	1000	1050	1100
7.5 min Filtrate, (cc)	6	3.5	2.75	2	1.75
30 min Filtrate, (cc)	12.5	7	6	4.5	4
Filter Cake Thickness, (mm)	3	1.6	1.4	1.35	1.35
Filter Cake Thickness (mm) * (32/25.4), (1/32 inch)	3.78	2	1.76	1.7	1.7
Mud Cake Resistivity, (ohm-mt)	2.1	1.3	0.85	0.77	0.77
Mud Cake Temperature, (°F)	73	72	74	74	74
Mud Cake NaCl Concentration, (ppm) (nomograph)	2700	4500	7000	7500	7500
Ca ⁺⁺ , (mg/l)	40	4	4	4	4
NaCl, (ppm)	182	247.5	330	330	330



Figure A.1. The Raw Waste Material of Mandarin Peels Powder (MPP)



Figure A.2. Very Small Chopped Pieces of the Mandarin Peels



Figure A.3. The Dried Small Pieces of Mandarin Peels



Figure A.4. The Mandarin Peels Powder (MPP)



Figure A.5. The Food Processor

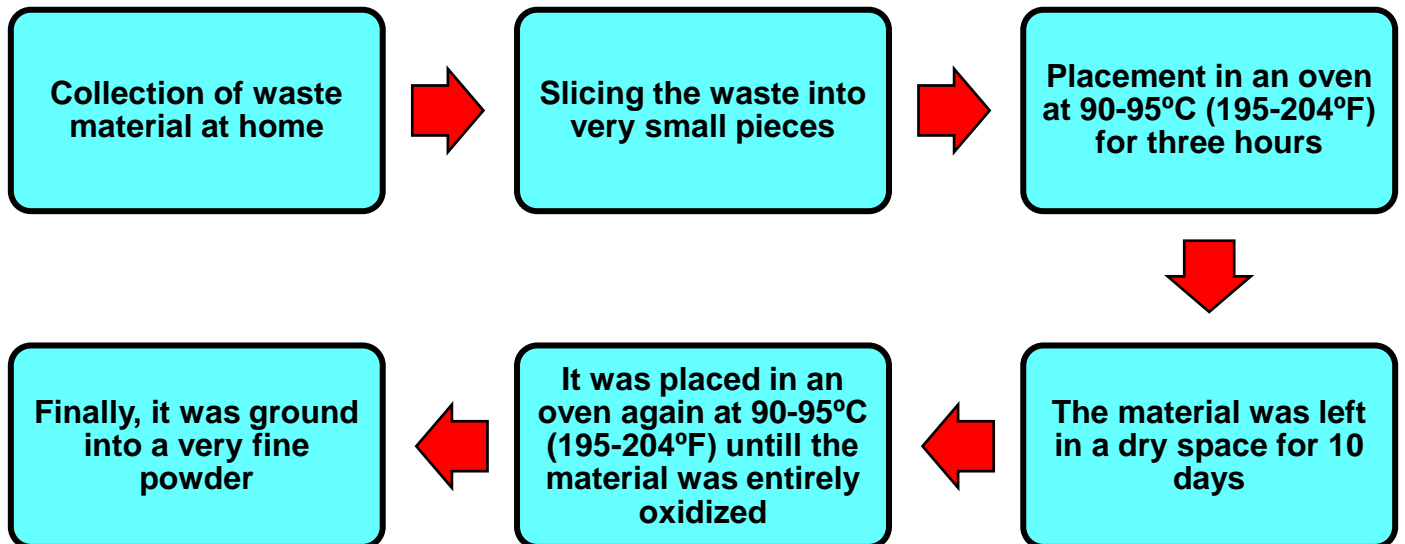


Figure A.6. The Workflow of Collection and Preparation of the Mandarin Peels Powder (MPP)

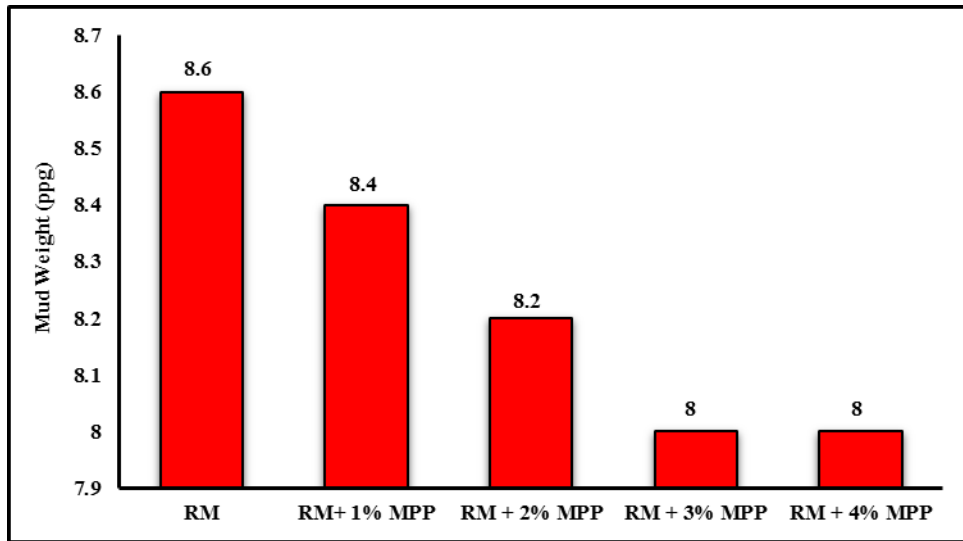


Figure A.7. The Effect of Mandarin Peels Powder (MPP) on Mud Weight (MW)

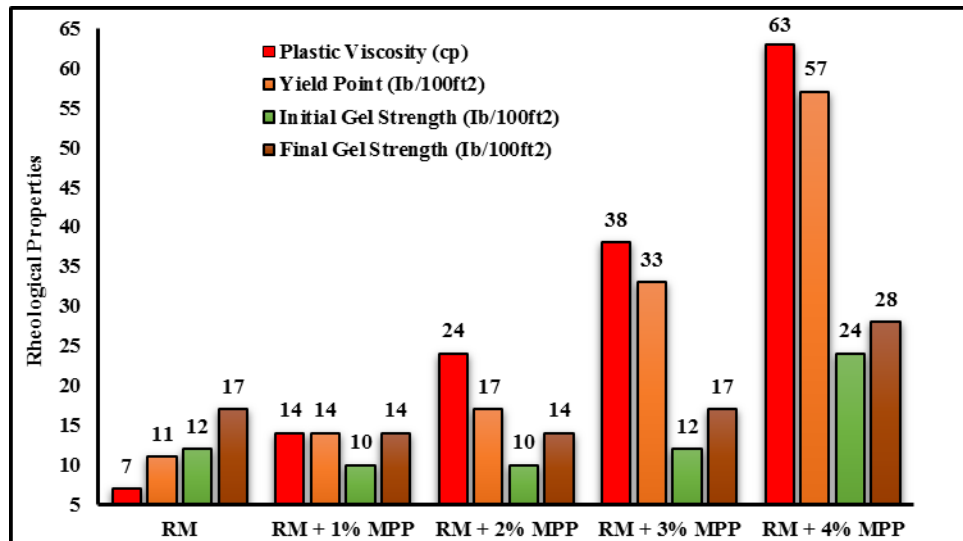


Figure A.8. The Effect of Mandarin Peels Powder (MPP) on the Rheological Properties

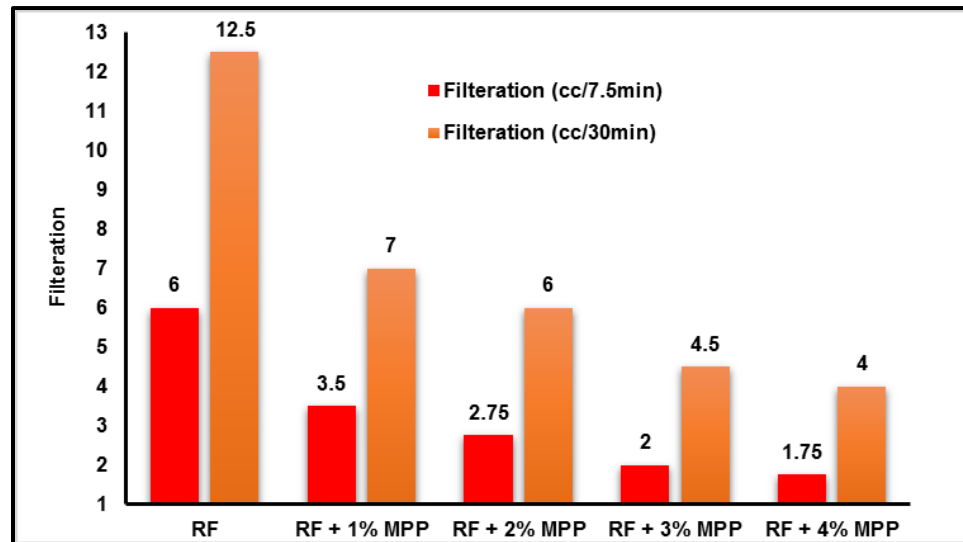


Figure A.9. The Effect of Mandarin Peels Powder (MPP) on Filtration

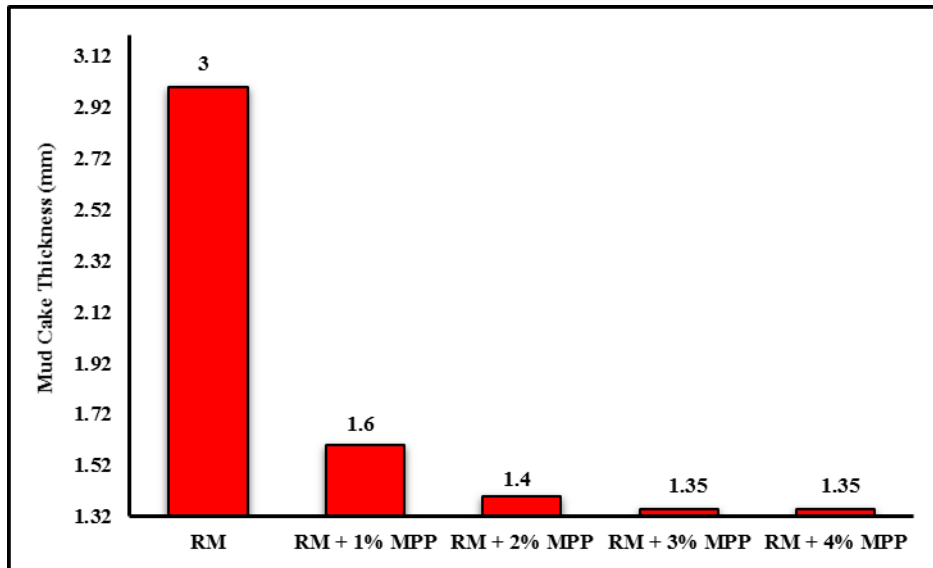


Figure A.10. The Effect of Mandarin Peels Powder (MPP) on Mud Cake Thickness

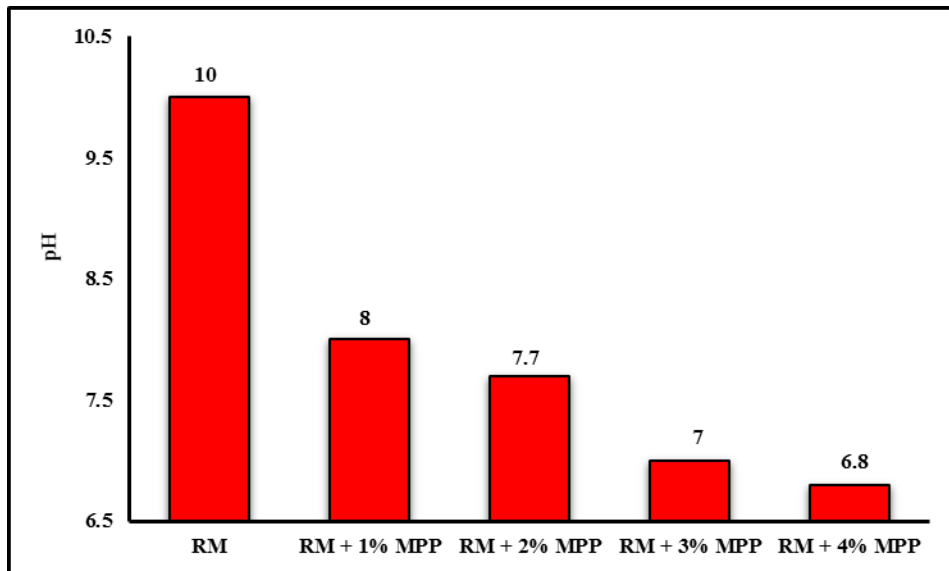


Figure A.11. The Effect of Mandarin Peels Powder (MPP) on pH