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Application of orange peel powder as an environment friendly additive for water-based drilling fluids for horizontal wells in parts of Upper Assam oilfields

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***Abstract*— The objective of this study is to develop an environment friendly water-based drilling fluid suitable for application in some horizontal wells of Upper Assam oilfields using natural materials additive. Orange (Citrus sinensis) peel, which is a food waste produced after eating or processing it as fruit juice, was the natural material selected as additive for the study purpose. The effects of orange peel powder on the performance of NDDF were evaluated. The experimental results showed that orange peel plays a good role in filtrate loss reduction, with the increase in concentration of orange peel powder, mud cake thickness increases, the apparent viscosity and plastic viscosity gradually increases, gel strength value increases, and 10 min gel strength shows a constant upward trend and 10 sec gel strength shows moderate increasing trend. The various properties of the prepared drilling fluids were compared with a few horizontal well data of Upper Assam oilfields and based on that, 2.5 % concentration of orange peel powder was found suitable for application with the NDDF. Overall, based on good properties shown by the prepared drilling fluids, orange peel powder is found to be green, environmentally friendly and efficient drilling fluids additive which can be used along with NDDF. After some chemical modifications, which will further improve its properties, it can be applied in other oilfields.**

Keywords: Environmental friendly water-based drilling fluid; NDDF; Natural materials additive; Orange peel powder

I. INTRODUCTION

Conventional drilling fluids used in the drilling operation contains many additives that causes environmental concerns. Due to increasingly astringent environment pollution laws, oil companies are developing environment friendly drilling fluids. In the Upper Assam area, for drilling the horizontal part of the wellbore, non-damaging drilling fluid (NDDF) is being used. Non-damaging drilling fluid (NDDF), which is a clay and barite free water-based drilling fluid, contains the following: water as base fluid, XC-Polymer or xanthan gum as viscosifier, pre-gelatinized starch (PGS) / PAC (LVG)/ PAC (RG) as fluid loss control agent, KCl as clay/shale inhibitor, linseed oil/polyol for lubricity, limestone powder/micronized $CaCO_3$ as weighing/bridging material and formaldehyde as bactericide [6]. However, it contains KCl which causes environmental problems due to the presence of Cl- ion, therefore in order to design an environment friendly water-based drilling fluid, we have to replace KCl with environment friendly additives [7]. The main aim of the study is to remove the environmentally objectionable additives from the NDDF and use environmentally safe additives to design an environment friendly water-based drilling fluid. Previous researchers have found that fruit peel powders e.g., fresh pomelo peel powder [5], mandarin peel powder [3] etc. can be used as shale inhibitor as well as fluid loss reducing agent and rheology modifier. Therefore, in this research work, locally found orange peel in fine powder form was taken as environment friendly additive. After preparing the drilling fluid with varying concentrations of orange peel powder, an optimum concentration was selected based on horizontal well drilling fluid data of some wells in Upper Assam area. The optimum/final drilling fluid was then observed for a duration of 20 days to check the change in properties with time. Moreover, an attempt has been made to study the effect of final drilling fluid on plants using greenhouse pot technique.

II. EXPERIMENTAL PROCEDURES

A. Materials

Fresh orange peels were collected and it went through drying and grinding process to obtain the powder form. The orange peels were first dried under sun for a week and then kept in hot oven for 24 hours. After that it was ground to fine powder form with the help of mortar and pestle. Further a sieve shaker was used to separate different particles according to their size. US standard mesh size sieve set as per American standard ASTM E-11 was used in the sieving process. Particles up to 74-micron (US #200 mesh) size can bridge and form filter cake on all formations except micro-openings or open fractures [9]. So, particles of this size can be said as most suitable to use in drilling fluid design. Therefore, particles passing through US #200 Mesh sieve or very Fine powder particles of orange peel powder samples were taken for drilling fluid preparation.

The general components used for formulation of NDDF are:

1. Base fluid - water
2. Viscosifier- XC polymer
3. Fluid loss control / coating agent - PGS (Pre-Gelatinized Starch),
4. Lubricity- Linseed oil

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5. Weighing and bridging materials: Limestone, MCC (Micronized Calcium Carbonate)
6. Bactericide- formaldehyde

B. Preparation of drilling fluid samples

Five different amounts of orange peel powder (0.5, 1, 1.5, 2 and 2.5% concentration by volume of water) were added to the water-based non-damaging drilling fluid. The effects of different amounts of orange peel powder on the rheological and filtration characteristics was tested and these properties were compared with horizontal well drilling fluid data obtained from ONGC, Sivasagar to determine the most suitable concentration of orange peel powder that can be used in the study area. After determining the optimum concentration of orange peel powder, the drilling fluid was then tested for a duration of 20 days to determine the degradation of the drilling fluid properties and to check whether they can still be used after 20 days. This test was considered for 20-day period, as the average drilling operations for drilling the horizontal part of the wellbore in Upper Assam area is 15-20 days. [11]

C. Measurement of Rheological and filtration properties

The rheological properties were measured with a M-3600 Grace viscometer following API 13B-1. After obtaining θ600 and θ300 values from the viscometer reading, plastic viscosity (PV), apparent viscosity (AV) and yield point (YP) can be calculated as,

$$PV\ (mPa.s) = \theta 600 - \theta 300$$

$$AV\ (mPa.s) = \theta 600 / 2$$

$$YP\ (lb/100ft^2) = \theta 300 - PV$$

$$YP\ (Pa) = 0.4788 \times (\theta 300 - PV)$$

For gel strength measurement, the viscometer is rotated in θ600 rpm for around 1 minute and allowed it settle for 10 sec. Then from the 3- rpm reading, the Gel 0 value is obtained. Gel 10 is the gel strength measured after 10 min wait time. In oil field unit, gel strength is measured in terms of $lb/100ft^2$ which can be converted into SI unit Pascal (Pa) by multiplying the conversion factor 0.4788 (1 Pa = 0.4788 $lb/100ft^2$).

Filtration properties were measured with Fann Series 300 API Low Pressure Low Temperature (LPLT) hydraulic Filter Press equipment. The fluid loss was observed for 30-minute time and value was recorded in ml. The filter cake formed in the filtration test was measured with the help of a steel ruler and recorded in mm. [1][4]

D. Plant growth test for environmental impact evaluation

Finally, with the help of greenhouse pot technique, the effects of the final drilling fluid with optimum concentration of orange peel powder on rice seed growth was observed and compared with conventional drilling fluid and without drilling fluid contamination to check its effects on environment. [10]

III. RESULTS AND DISCUSSIONS

Well cards of seven horizontal wells of Upper Assam oilfield were collected from ONGC and the various properties of non-damaging drilling fluid used to drill the horizontal section of these wells were obtained. From these data, an average value and range were calculated. Table 1 shows the various properties of NDDF and their range and average value.

Table 1: NDDF data of horizontal wells (source: ONGC)

Well name	Mud weight, Kg/m^2	Funnel Viscosity, seconds	Fluid loss, ml	Plastic Viscosity, cP (1 cP = 1 mPa.s)	Yield Point, $lb/100ft^2$	Gel_0, $lb/100ft^2$	Gel_{10}, $lb/100ft^2$
Geleki # 1	1080-1130	48-57	5-5.8	16-20	28-34	5-8	12-18
Geleki # 2	1050-1090	56-65	5.2-6	19-20	30	9-11	18
Geleki # 3	1070-1110	48-55	5.4-7	12-15	18-35	8-11	14-20
Geleki # 4	1040-1060	54-60	6-8	17-24	26-40	10-16	15-18
Rudra Sagar # 1	1050-1070	45-50	4-6	13-16	23-28	7-9	13-15
Rudra Sagar # 2	1040-1060	51-57	8-8.5	13-15	29-36	10-12	16-18
Lakwa #1	1100-1140	48-52	5-7	11-18	24-28	9-12	14-20
Range	1040-1140	45-65	4-8.5	11-24	18-40	5-16	12-20
Avg. Value	1090	55	6.25	17.5	29	10.5	16

Five NDDF samples were formulated by adding different concentrations of orange peel powder (0.5, 1, 1.5, 2 and 2.5 %) keeping the other components constant as: distilled Water, XC-Polymer: 0.3 %, PGS: 3 %, Micronized $CaCO_3$: 5%, Limestone powder: 3 %, Biocide: 0.1 %, and Linseed oil: 5% in gm/100ml basis. [2][6][8]

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The table 2 shows the rheological and filtration properties of non-damaging drilling fluids with five different concentrations of orange peel powder (OPP). Figures 1-7 shows the change in different parameters with increasing concentration of OPP.

Table 2: Properties of NDDF with varying OPP concentration

Parameters		Without OPP	Orange peel powder concentration (%)				
			0.5	1	1.5	2	2.5
Funnel Viscosity, seconds		47	51	53	54	55	56
Apparent Viscosity, (mPa.s)		21.23	23.56	26.25	28.07	30.6	32.88
Plastic Viscosity, (mPa.s)		12.53	12.73	14.28	15.02	16.58	17.9
Yield Point	Oil field unit, lb/100ft^2	17.4	21.65	23.94	26.1	28.03	29.96
Yield Point	SI unit, Pa	8.33	10.36	11.46	12.49	13.42	14.34
Gel 0	Oil field unit, lb/100ft^2	5.09	5.87	6.28	7.43	7.82	8.76
Gel 0	SI unit, Pa	2.44	2.81	3.01	3.56	3.74	4.19
Gel 10	Oil field unit, lb/100ft^2	6.14	6.84	7.32	8.56	9.82	11.3
Gel 10	SI unit, Pa	2.94	3.27	3.50	4.10	4.70	5.41
Filtration Loss (ml)		8.6	7.9	7.6	7.2	6.7	6.2
Mud cake thickness (mm)		0.26	0.27	0.28	0.28	0.29	0.30
Mud density (Kg/m^2)		1071	1073	1075	1077	1080	1083

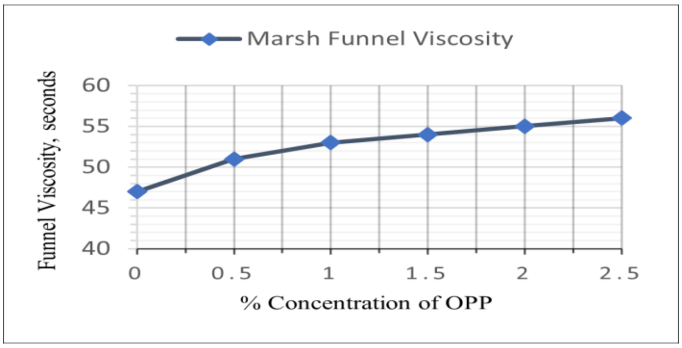

Fig 1: Funnel viscosity vs Concentration of OPP

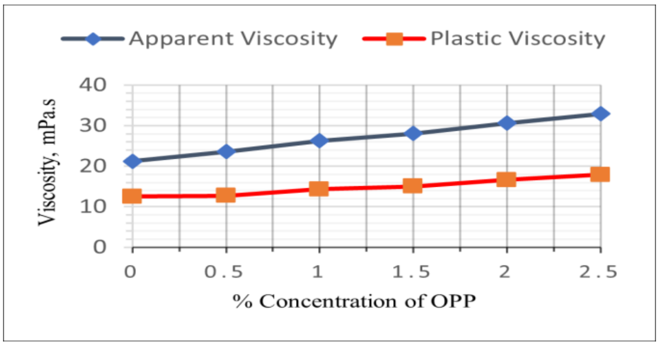

Fig 2: Viscosity vs Concentration of OPP

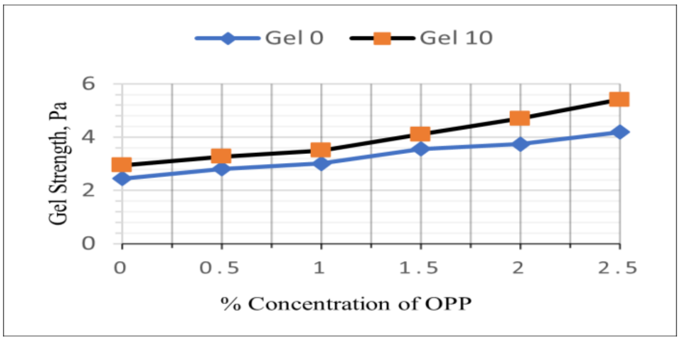

Fig 3: Gel strength vs Concentration of OPP

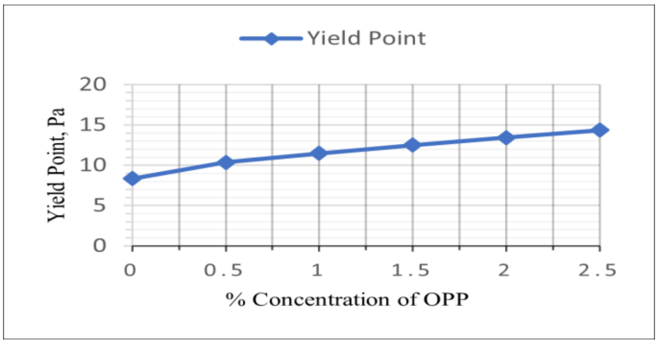

Fig 4: Yield point vs Concentration of OPP

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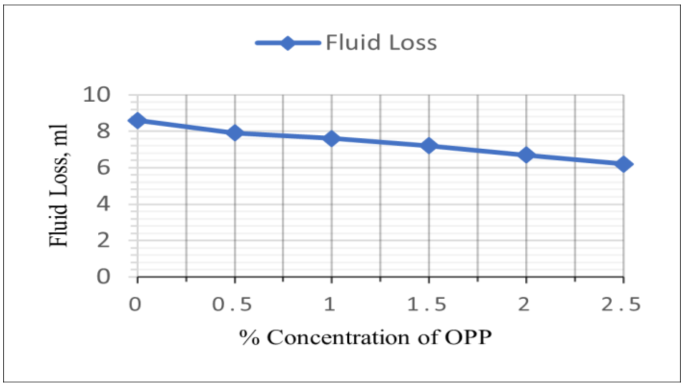

Fig 5: Fluid loss vs Concentration of OPP

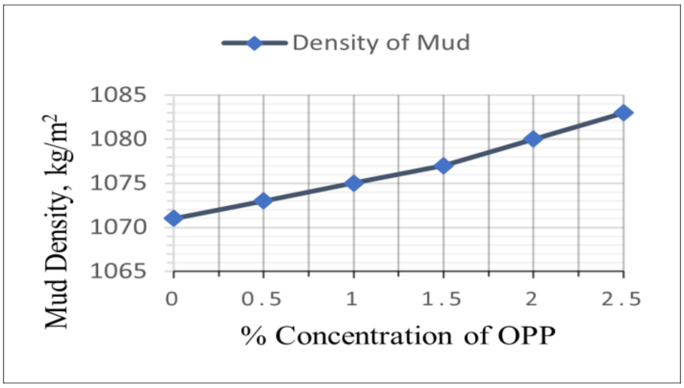

Fig 7: Mud density vs Concentration of OPP

From the figure 1, we can observe the variation in funnel viscosity with different concentration of OPP. As the OPP concentration increases, the funnel viscosity also increases. It shows that the prepared mud is getting thicker with the addition of OPP. Figure 2 shows the increasing trend of apparent viscosity and plastic viscosity with increasing OPP concentration. With the increasing concentration of OPP, the Gel 0 and Gel 10 value increases, and 10 min gel strength shows a constant upward trend with 10 sec gel strength showing moderate increasing trend as seen from figure 3. The yield point shows a moderate upward trend in figure 4. Figure 5 shows the decreasing amount of fluid loss as OPP amount increases, which shows that OPP is reducing the fluid loss. From the figures 6 and 7, mud density increases with addition of OPP and since the amount of OPP is increasing, more suspended particles can accumulate in the static filtration conditions and therefore the mud cake thickness shows slightly increasing trend.

From the Table 1, the ranges and average values of NDDF parameters are obtained as,

Mud density (Kg/m^2) = 1040-1140, 1090
Funnel viscosity (Seconds) = 45-65, 55
Fluid loss (ml) = 4-8.5, 6.25
Plastic viscosity (mPa.s) = 11-24, 17.5
Gel 0 (lb/100ft^2) = 5-16, 10.5
Gel10 (lb/100ft^2) = 12-20, 16
Yield point (lb/100ft^2) = 18-40, 29

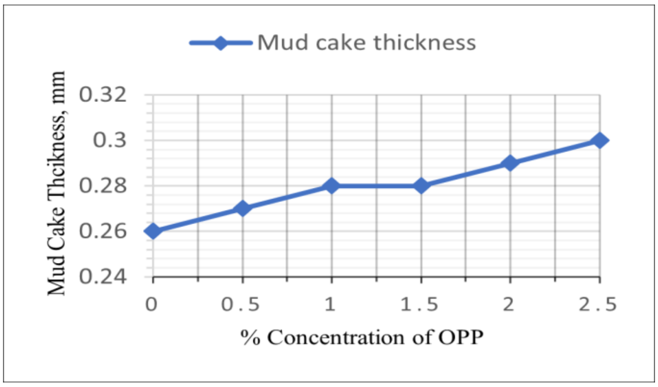

Fig 6: Mud cake thickness vs Concentration of OPP

Comparing these values with the OPP added NDDF data from table 2, we can see that the 2.5 % concentration OPP drilling fluid is the most suitable for application in the targeted study area among the five drilling fluids. This drilling fluid shows the optimum properties and comes under the designed range of the study area.

This 2.5 % OPP NDDF was taken as the final drilling fluid and it was observed over a time period of 20 days for any changes in the drilling fluid properties. The drilling fluid was kept in ambient temperature and atmospheric pressure conditions in the laboratory and effect of mud properties with change in time periods were investigated. The drilling fluid parameters were measured as an order of 0-day, 1-day, 7-days, 15-days and 20-days. Figures 8-15 shows the various mud properties with change in time.

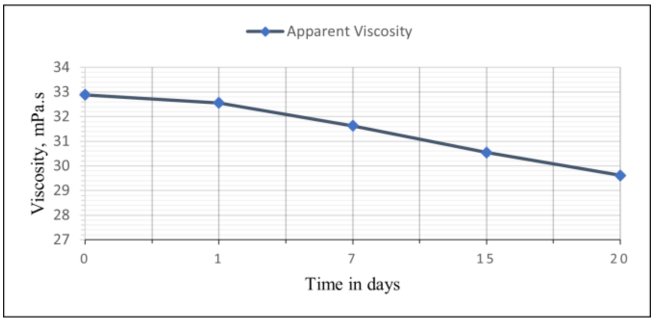

Fig 8: Apparent viscosity with change in time

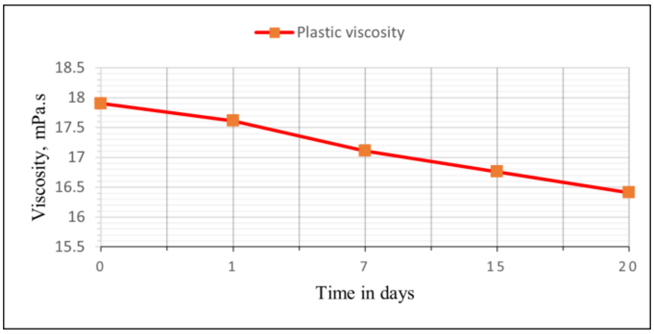

Fig 9: Plastic viscosity with change in time

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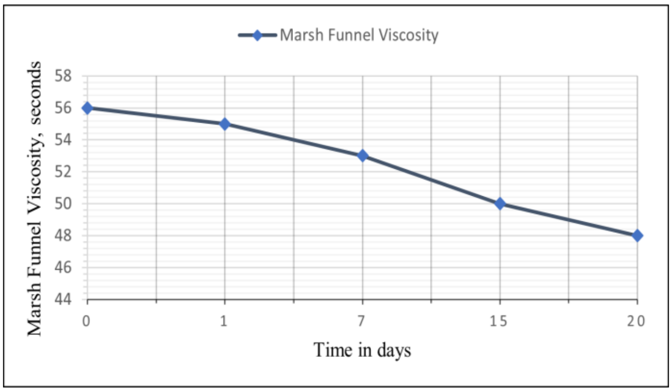

Fig 10: Marsh funnel viscosity with change in time

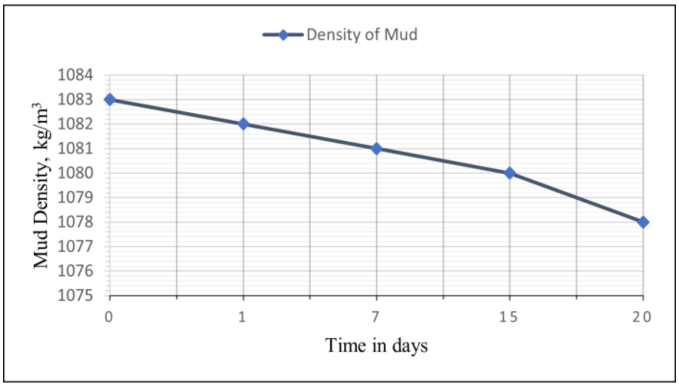

Fig 11: Mud density with change in time

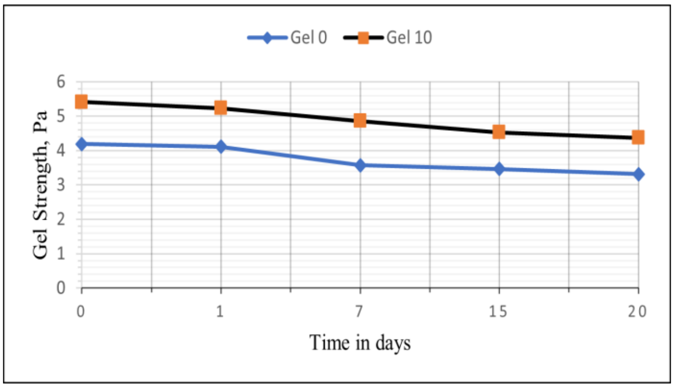

Fig 12: Gel strength with change in time

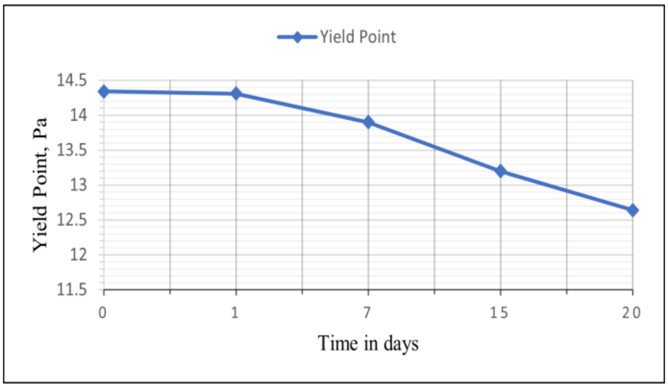

Fig 13: Yield point with change in time

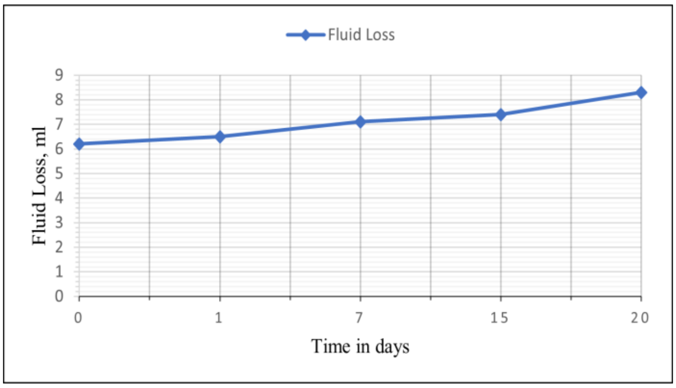

Fig 14: Fluid loss with change in time

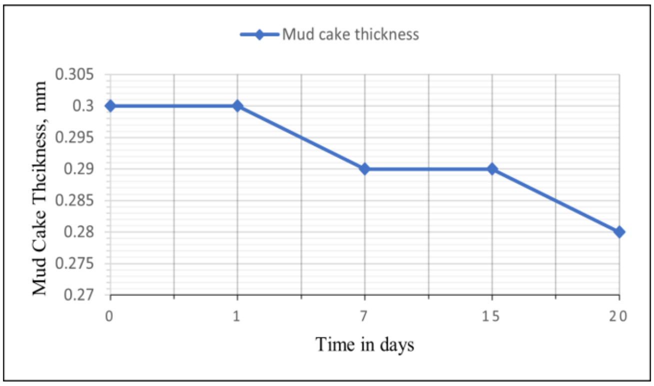

Fig 15: Mud cake thickness with change in time

It can be observed from the figures 8-15, that all the mud properties are degrading with increasing time span. The investigated trends are as follows:

- Funnel Viscosity: Decreases with increasing time.
- Apparent Viscosity: Decreases with increasing time.
- Plastic Viscosity: Decreases with increasing time.
- Density of mud: Slightly decreases with increasing time.
- Gel Strength: Decreases with increasing time.
- Yield Point: Decreases with increasing time.
- Fluid Loss: Increases with increasing time.
- Mud Cake Thickness: Slightly decreases with increasing time.

It can be seen that all the mud properties are decreasing and it is due to the bio-degradation of the additives, mainly the xanthan gum and starch. They show a little change after 1 day period and then shows a gradual decrease up to the 20th day. Mud cake thickness decreases slightly due to less availability of additives because of bio-degradation. It results in increase in fluid loss volume, as it has increased from 6.2 ml in the beginning to 8.3 ml after 20 days. The drilling fluid starts to lose gel strength after keeping it over a period of time. These drilling fluid properties were again compared with ONGC data in table 1, and it was found that although the properties decrease significantly, they still come within the design range value. Hence, it be concluded that this drilling fluid with 2.5 % concentration of OPP is suitable for use in the target study area.

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The final 2.5 % OPP drilling fluid was taken for greenhouse pot experiment to check whether it is environmentally friendly. The effect of final drilling fluid, conventional drilling fluid and plain water on the growth of rice (Oryza sativa) seeds were studied in this test. Rice seeds were germinated after keeping it semi-submerged in plain water for around 72 hours. Both the drilling fluids were mixed with small amount of soil and were put into two separate containers. One container with only soil and water mixture was also prepared. Around 100 germinated rice seeds were put into each container and seed growth rate was observed for a time period. The table 3 shows the growth data of rice seeds in each container.

Table 3: Rice seed growth data

Time period	Average Seed growth length in cm		
	Water + soil	OPPDF + soil	Conventional drilling fluid + soil
5 days	2	1.8	1.5
7 days	3.6	2.6	1.9
10 days	4.7	4.1	3.6
13 days	6.8	6.2	5.2
15 days	9.3	8.1	6.8

These data are plotted in column chart to show the growth rate with time. Figure 16 shows the growth rate of rice seed with increasing time.

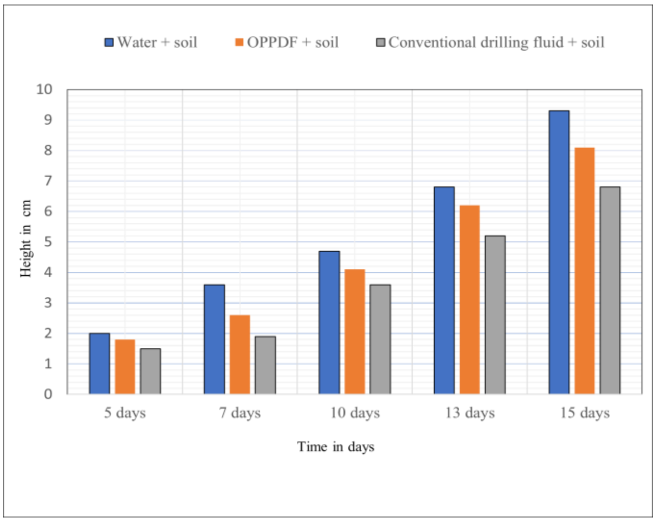

Fig 16: Rice seed growth rate vs time

From the figure 16, it can be observed that the average height of rice seed planted in OPP drilling fluid and soil mixture shows good growth almost comparable to the growth in water-soil mixture. After 15-day period, no seedlings were dying or turning yellow in color, representing their good growth. Hence it can be concluded that this OPP drilling fluid will not affect the nearby paddy fields and plant growth even if the soil/water adjacent to the drilling site is contaminated with it. As the drilling fluid was formulated with environment friendly additives, the discharge of OPP drilling fluid will not be a major environmental issue.

IV. CONCLUSION

From the above study, the flowing conclusions were obtained.

- Orange peel powder is a good rheological modifier and fluid loss control agent that can be used along with PGS for formulation of NDDF.
- With the increasing concentration of orange peel powder, the rheological parameters increases and the 2.5 % concentration OPP drilling fluid is the most suitable for application in horizontal wells in the target study area of Upper Assam oilfield.
- The final drilling fluid is stable up to at least 20 days, as the drilling fluid parameters measured in the 20-th day comes under the design range value for horizontal wells in Upper Assam oilfield.
- The final drilling fluid will not affect the plant growth rate near the drilling site even if it is somehow exposed to nearby soil and water.
- The final drilling fluid shows plant seed growth rate almost equivalent to that of soil and water mixture and no seedlings were found dying or turning yellow in color showing its environment friendly nature.

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CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding the experimental study shown in this work.

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