**Economics of Local Materials as Base Fluids in The Formulation of an Oil Based Mud**

By

Sarah A. Akintola*[1] and E. B. Atere*

***ABSTRACT***

*The use of drilling fluid is an important aspect in drilling operations as its critical to ensure a safe and productive oil or/ and gas well. In the bid to protect the environment and reduce environmental pollution resulting from drilling activities while using the No. 2 diesel, it is necessary to search for an alternative that will be suitable, locally available, easily affordable vegetable oils which is environmentally friendly and non-toxic as base fluid. This study is aimed at investigating the properties and economics analysis of the use of non-toxic, biodegradable locally obtainable oil from the palm kernel seed (Oil X) and coconut (Oil Y) as base fluid in the formulation of an Oil Based Mud. The rheological and filtration properties of the mud samples were evaluated using the API Recommended Standard, while the economics analysis was performed using the Net Present Value (NPV) and discounted profit to investment ratio (DPI) models. The results of the rheological, filtration and physiochemical properties for both X-OBM and Y-OBM, showed the possibility of the use of oil X or Y as base fluid as against No. 2 diesel. The result from the NPV model showed that the use of oil X or Y provided a higher NPV compared to those of No. 2 diesel mud even though the cost of No. 2 diesel was lower than those of X and Y oils. Also the discounted profit to investment ratio (DPI) was also better for mud formulated from the vegetable oil muds Although the initial cost of formulating mud samples using oil X or Y compared to No. 2 diesel Oil Base Muds (OBM) seems higher, consideration of their fire capacity resistance, nonimpact on the environmental and the cost of disposal of OBM the application of vegetable oil X or Y is more viable than No. 2 diesel in the industry*

**Key words:** Coconut oil (Oil Y), Palm Kernel seed (Oil X), Diesel, Net Present Value, Discounted Profit to Investment Ratio

## 1.0 Introduction

The Nigerian oil and gas industry have in the past few years witnessed a changing terrain with the advent of the Local Content Act. The local content act encourages the substitution of imported materials with locally obtainable replacement. Generally, Water Based Mud (WBM) and Oil Based Mud (OBM) are the most widely used drilling fluid types in the oil and gas industry. Oil based systems were developed and introduced in the 1960s to help address several drilling problems most notably swelling or sloughing of clays upon reaction with WBMs. But the need to protect the environment and reduce environmental pollution resulting from the use of No. 2 diesel as base fluid in OBM has led to the quest for an environmentally friendly suitable substitute for diesel. The alternative to diesel fuels must be technically and environmentally acceptable and economically viable. As a result, vegetable oils shall be considered as viable alternatives to diesel, although it has high viscosity due to large molecular weight and bulky molecular structure.[1] Also the use of vegetable oils will help strengthen the relationship and interaction between the agricultural and energy sector.

*[1] Department of Petroleum Engineering, University of Ibadan, Ibadan Oyo State Nigeria.
[1]e-mail: sarah.akintola@ui.edu.ng

[1] Anastopoulos, G.; Zannikou, Y.; Stournas, S.; Kalligeros, S. (2009), Transesterification of vegetable oils with ethanol and characterization of the key fuel properties of ethyl esters. Energies 2, 362–376.

A lot of effort has been made by researchers since 1991 to date on the use of vegetable oil as base fluid in the formulation of an environmentally friend Oil Base Muds. Yassin et al[2] and Ismail, A.R.[3], these researchers used palm oil as the base fluid and determined the toxicity of the use of palm oil but Yassin et al further examined the rheological and filtration properties of the mud samples. Although Yassin et al, noted that the oil had a high plastic viscosity, but they all noted that the oil had low toxicity, high flash point and good emulsion stability. Sachez et al,[4] in their work evaluated the toxicity and biodegradability of the oil-base drilling fluids formulated from the use mineral oil and palm oil against that of diesel, their results show that mineral and palm tree oil based fluids are not toxic while diesel showed high toxicity levels In 2010, Ogunrinde and Dosumu[5] in their study used both palm oil and groundnut oil as base fluid in an OBM. They determined the rheological properties and the toxicity
of the mud sample. From their results they concluded that the use of both oil as base fluid should be encouraged. Researchers now are looking into the use of synthetic oils as being more environmentally friendly than the conventional diesel or mineral oil-based mud.

Fadairo et al,[6] using jatropha and canola oil as base fluid developed an ANN model for predicting the down hole mud density of these mud sample. The No. 2 diesel was also determined and used as control. Their results showed that both jatropha and canola oil possessed a great prospect. In 2012, Adesina et al[7] used jatropha and rapeseed oil while Apeleke et al[8] used rapeseed oil alone as base fluids in the formulation of an OBM. They all carried out the rheological and filtration properties test and concluded that these oils were good suitable for No. 2 diesel. Ogeleka et al[9] carried out a study to evaluate the toxic effect of diesel OBM using brackish water shrimps obtained from Abua in Rivers state as the test species for the study. The water shrimps were exposed to varying concentrations of drilling fluid waste and it was observed that the mortality rate was dependent on the drilling fluid waste concentration.

Anawe et al[10] investigated the use of jatropha OBM and groundnut OBM as alternatives to diesel OBM. The rheological properties of all three muds were determined at different temperatures. Jatropha OBM was observed to possess the highest viscosity and density of all the three mud

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[2] Yassin, A.M; Kamis, and Abdullahi, M.O. (1991): Palm Oil Diesel as a Base Fluid In Formulating Oil Based Drilling Fluid . SPE Paper23001

[3] Ismail, A.R. (2011): Managing the Environmentally Friendly Drilling Fluid in Petroleum Industry. The 2nd International Conference on Disaster Management, Surabaya, Indonesia, 3- 5 May.

[4] Sáchez, G; León, N, Esclapés, M; Galindo, I; Martínez, A; Bruzual, J; Siegert, I (1999) *Environmentally Safe Oil-Based Fluids for Drilling Activities"* SPE 52739, Paper presented at SPE/EPA Exploration and Production Environmental Conference held in Austin, Texas, 28 February–3 March 1999.

[5] Dosumu A and Ogunrinde, J.O (2010): Development of Environmentally Friendly Oil Based Using Palm Oil and Groundnut Oil SPE Paper 140729.

[6] Fadairo, A., Ameloko, A., Adeyemi, G., Ogidigbo, E. and Airende, O. (2012). *Environmental impact evaluation of a safe drilling mud.*

[7] Adesine F. David, O and Olugbenga, F. (2013): Investigating the Cutting Carrying Capacity and the Effect of Drilled Cutting on Rheological Properties of Jatropha Oil Based Mud Paper SPE 167551.

[8]

[9] Ogeleka, D.F. and Tudararo-Aherobo, L.E. (2013). *Assessment of the toxic effects of oil-based drilling mud (drilling waste) on brackish water shrimp (palaemonetes africanus).*

[10] Paul Apeye Lucky Anawe, Vincent Enon Efeovbokhan, A. A. Ayoola and Otuekong Akpanobong. "Investigating alternatives to diesel in oil based drilling mud formulation in the oil industry" Journal of Environment and Earth Sciences, 2014. 4 (14). pp. 70-77. ISSN 2224-3216

samples. Akintola et al[11] examined the filtration properties of using melon, groundnut soybean and palm oil as base fluid. Their result showed the ranking in order of better and effective filtration properties as shown melon, groundnut soybean and palm oil. Agwu et al[12] carried out a comparative study on diesel and soybean oil as base fluid for an OBM. they observed that diesel OBM lost more filtrate during the filtration test compared with that of soybean OBM and were able to conclude that the soybean OBM would be better suited as drilling fluid compared to diesel OBM.

The mud samples density was obtained using the pressured mud balance. The rheological properties were determine using the Fann 35A and calculated using the equations 1.0 – 3.0 while the API Filter press was used to obtain the 30mins water loss.

$$Av = \frac{\theta_{600}}{2.0} \qquad 1.0$$

$$Pv = \theta_{600} - \theta_{300} \qquad 2.0$$

$$Yp = \theta_{300} - Pv \qquad 3.0$$

Economic analysis is carried out to compare and contrast between projects or alternatives in order to choose which is most cost effective, viable and produces the most benefits. The analysis was carried out using the Net Present Value and Profitability Index by applying the equations 4.0 and 5.0, respectively.

$$NPV = -I + \frac{CF_t}{(1+i)^t} \qquad 4.0$$

$$DPI = \sum_0^t DCF_t * \frac{1}{I} = \frac{NPV}{I} \qquad 5.0$$

## 2.0 MATERIALS AND METHODOLOGY

**2.1 Materials:** No. diesel oil, palm oil, coconut oil, and organophilic clay. The additives used for formulating of the mud were obtained from MI-Swaco Limited, Port-Harcourt, Rivers State The chemicals used were of analytical grade.

**2.2 Apparatus:** These include: Weighing scale, mud balance, sample containers, mixer, measuring cylinders, viscometer, thermometer, mixer, hydrometer, Pensky-Martens closed cup flash tester, Kehler model k-16270, Capillary Viscometer (Herzog Gmbh MP480), pycnometer, beakers, Soxhlet Extractor and API Filter press

### 2.3 Extraction of Oil from Palm Kernel Seeds and Coconuts

The palm kernel seeds were obtained from a farm in Ondo state while coconuts were purchased from a local market in Ibadan, Oyo State. The extraction of the oils was carried out using the Soxhlet apparatus n-haxane was used as solvent.

### 2.4 Determination of Physicochemical Properties of the Extracted Oils



[11] Akintola, S. Oriji, A.B. and Momodu, M. (2014): Analysis of Filtration Properties of Locally Sourced Base Oil For The Formulation of Oil Based Drilling Fluids. Scientia Africana, Vol 13 No 1 Pp 171 -177

[12] Agwu, O.E., Anietie, O.N. and Udoh, F.D. (2015). *A comparative study of diesel oil and soybean oil as oil-based drilling mud.*

To know if the base fluid will have the desired properties, its physicochemical properties were determined, four properties density, pour point and flash point and kinetic viscosity were measured in the department of Petroleum Engineering Laboratory, University of Ibadan:

**a) Density and Specific Gravity:** The density of the extracted oils was determined using a (50ml). pycnometer and a weighing balance. The density was calculated using the equation 6.0 while the specific gravity was determined using a hydrometer

$$\boldsymbol{Density, \rho = \frac{Mass\ (m)}{Volume\ (v)} \quad 6.0}$$

**b) Pour Point:** The ASTM D97 method was used to determine the pour points

**c) Flash Point:** The Pensky-Martens closed cup flash tester, Kehler model k-16270 was used to obtain the flash point

**d)** Kinematic Viscosity: The Kinematic Viscosity was determined using the Capillary Viscometer

## 2.5 Formulation of Mud Sample

A 9 ppg mud was formulated as presented in the Table 1.0 using the different base oils (Oil X, oil Y and diesel oil) with an oil water ratio of 70:30 was used.

**Table 1.0: Formulated 9.0 ppg Mud Sample with the Different Oil as Base Fluid**

| **Material** | **Quantity** | **Concentration (field units)** | **Mixing Order** | **Mixing Time (mins.)** |
|---|---|---|---|---|
| Base Oil (X, Y and Diesel) | 218.3 | ppb | 1 | |
| VG Plus | 6.00 | ppb | 2 | 12 |
| Lime | 8.00 | ppb | 3 | 3 |
| Novamul | 8.00 | ppb | 4 | 10 |
| NaCl | 5.00 | | | |
| Water | 88.62 | ppb | 5 | 10 |
| Versatrol | 8.00 | ppb | 6 | 5 |
| Barite | 86.06 | ppb | 7 | 5 |

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## 2.6 Economic Analysis

For the economic analysis, a well drilled at Area AB1 foothills in the Alberta region of Canada was used as case study. The depth data and costs were obtained from the Petroleum Services Association of Canada (PSAC) 2015 well costs summary brochure. The casing length(ft) and hole size (inches) for surface, intermediate and production casing for the well drilled into an oil formation with a Total depth of 14,763 feet using a 6.625 inches drill pipe is shown in the Table 2.0. The well has a porosity of 30% and an assumed initial daily well production of 500 barrels per day. The mud cost is made up of the cost of the oil, cost of treatment of cuttings before disposal and cost of transportation and disposal of cuttings. It is assumed that stained cuttings would require little to no treatment cost.

**Table 2.0: Casing Length(ft) and Hole Size (Inches) for Surface, Intermediate and Production Casing**

| Type of Casing | Casing Length(ft) | Hole Size (Inches) |
|---|---|---|
| Surface | 1,969 | 16.00 |
| Intermediate | 8,990 | 13.375 |
| Production | 3,805 | 8.5 |

An economic model Is prepared using the well costs and calculated mud costs if the well was drilled using X, Y or D OBM. The required mud volume and volume of cuttings generated were determined using the equations 7.0 and 8.0

$$Required\ Mud\ Volume = \frac{d^2}{1029.4} * D \qquad 7.0$$

$$Volume\ of\ cuttings\ generated = \frac{d^2 + (1-\phi)}{1029.4} * D \qquad 8.0$$

**Cost Requirements**

Well cost excluding mud cost = $ 14,337,890.00

Treatment cost = $50 per barrel; Haulage and disposal cost = $20 per barrel

The equation 9.0 is used to obtain the mud cost requirement for the different base fluids

Mud cost requirements =

$$\left(oil\ cost\ in \frac{\$}{bbl} * reqd.\ oil\ volume\right) + cuttings\ volume * (treatment\ cost + disposal\ cost) \qquad 9.0$$

The following steps were used in the preparation of the economic model:

- The mud and rock cuttings volume that would be required to drill through the production and intermediate zones only assuming the surface zone would be drilled with a water-based mud was determined. Also, the mud costs inclusive of cuttings treatment and disposal costs that would be required to drill through intermediate and production zones was calculated.
- An NPV model using revenue obtained from a 12years production forecast using exponential decline curve analysis was prepared and calculate other economic decision-making parameters.

## 3.0 Results and Discussion

a) **Oil Recovery Breakdown**

| | |
|---|---|
| Mass of unbroken seed | = 5.36 kg |
| Mass of broken seed | = 3.78 kg |
| Mass of water expelled from seed | = 5.36 – 3.78 = 1.58 kg |
| Mass of shell | = 1.048 kg |
| Mass of extracted oil, Y | = 543.66 g |
| Weight of nuts **X** | = 2115.29 grams |

Weight of extracted oil X = 747.35 grams
Dry weight of pycnometer = 19.31 grams
Viscometer size and constant = 200 and 0.1, respectively
Weight of pycnometer filled with oil Y and X = 65.31 and 64.81 grams, respectively.
The dynamic and kinematic viscosity is calculated using equations 7.0 and 8.0

Dynamic viscosity= density ($\rho$) * flow time ($t$ )*viscometer constant( $K$) 7.0

Kinematic viscosity = flow time ($t$ )*viscometer constant( $K$) 8.0

**b) Physiciochemical Properties of Oil X and Y:** The **r**esults of the physiochemical properties are shown in Table (2).

**Table 2.0: Physiciochemical Properties of Oil X and Y**

| | **Specific Gravity** | **Dynamic Viscosity (cp)** | **Kinematic Viscosity (cp)** | **Pour point ($^oC$)** | **Flash point ($^oC$)** |
|---|---|---|---|---|---|
| Oil X | 0.91 | 32.5 | 29.45 | 20 | 225 |
| Oil Y | 0.92 | 13.1 | 12.05 | 20 | 242 |

**2) Density of Mud Sample:**

The density of the mud sample was measured at temperature of 30$^o$C and the results presented in the Table 3.0. It can be observed that No.2 diesel OBM had the least density followed by X OBM and then Y OBM. The increase in mud density follows the trend of the density of the base oils this shows that the density of the base oil plays a role in the overall density of the mud system. The mud density result also shows that X OBM and Y oil OBM would do a good job in controlling formation pressures and prevention of influx of formation fluids into the wellbore.

**Table 3.0: Mud Density(ppg) at 30$^o$C**

| **Mud Sample** | **Density(ppg) @30$^o$C** |
|---|---|
| XOBM | 9.31 |
| YOBM | 9.30 |
| DOBM | 8.76 |

**3) Rheological Properties**

The mud samples rheological properties were determined by applying the equations 1.0 – 3.0. From the plot of the plastic viscosity against temperature, Figures 1.0, it is observed that the plastic viscosity of X and Y OBMs, increases before it starts to decrease as temperature increase. but that of diesel OBM decreased steadily with increasing temperatures. At lower temperatures, the X OBM and Y OBM, had values of plastic viscosities higher than the recommended values. This can be attributed to the high value of the specific gravity of their base fluid Overall, a decrease in plastic viscosity with increasing temperatures can be observed for the three mud systems but from the three mud systems, DOBM has the least plastic viscosity followed by X OBM and Y OBM.

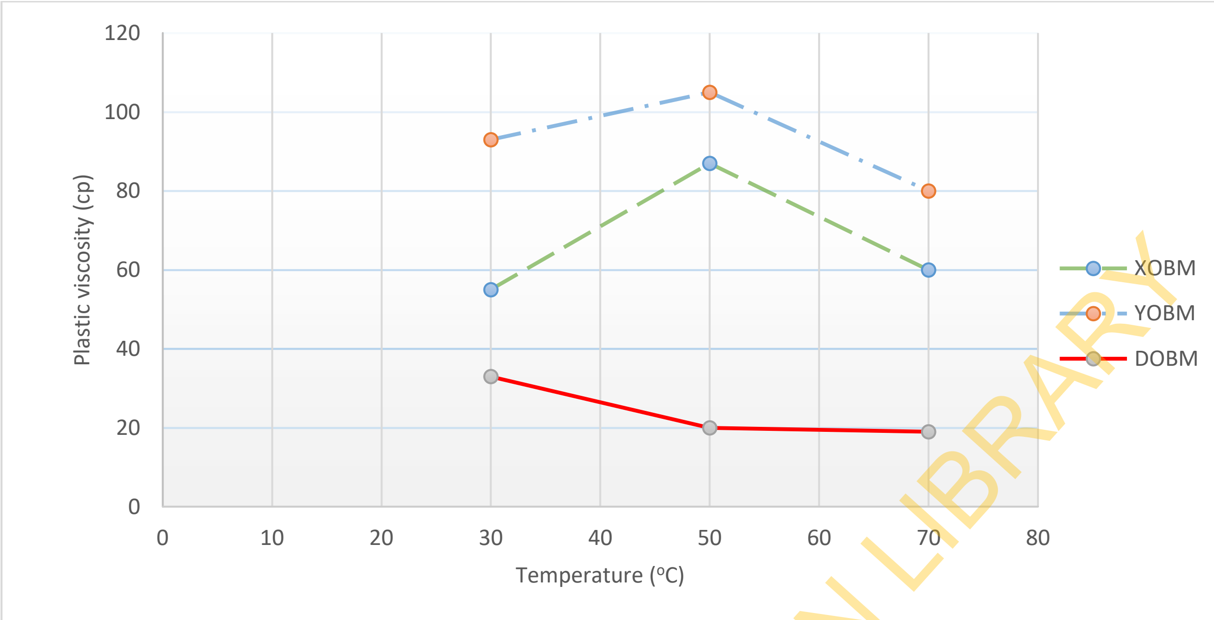


**Figure 1.0: Plastic viscosity (cp) against Temperature ($^{o}$C) for X OBM, Y OBM and DOBM**

From the Figure 2.0 it can be observed that the yield point decreases with increasing temperatures for the three mud systems. A decrease in yield point values with increasing temperature is as a result of the effect of temperature on the intermolecular bonds between the molecules of the mud. High

temperatures weaken the bonds and as a result, at higher temperatures, less stress would be needed to break the bonds and initiate flow. At surface temperatures, the X OBM had the highest yield point followed by the Y OBM and then the DOBM. At temperatures above 40$^{o}$C, the yield point of the X oil continues to decrease drastically. This shows that at higher temperatures, the X OBM can perform like the diesel OBM based on yield point values.

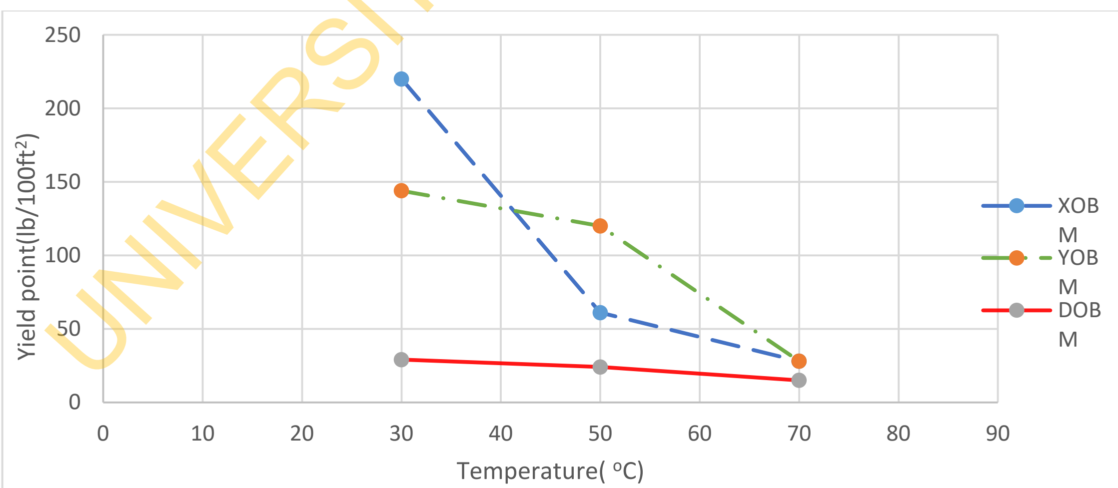


**Figure 2.0: Yield point against Temperature ($^{o}$C) for X OBM, Y OBM and DOBM**

From Figure 3.0 the gel strengths for all the mud systems decrease with increasing temperature. Decreasing gel strength with increasing temperature is the effect of temperature on the intermolecular bonds within the mud molecules as the bonds tend to weaken as temperatures increase. At surface temperatures, X OBM has the highest gel strength and diesel OBM has the least gel strength. However, gel strength values of X OBM decrease drastically with increasing temperature and equal the gel strength value of diesel OBM at 67$^{o}$C.

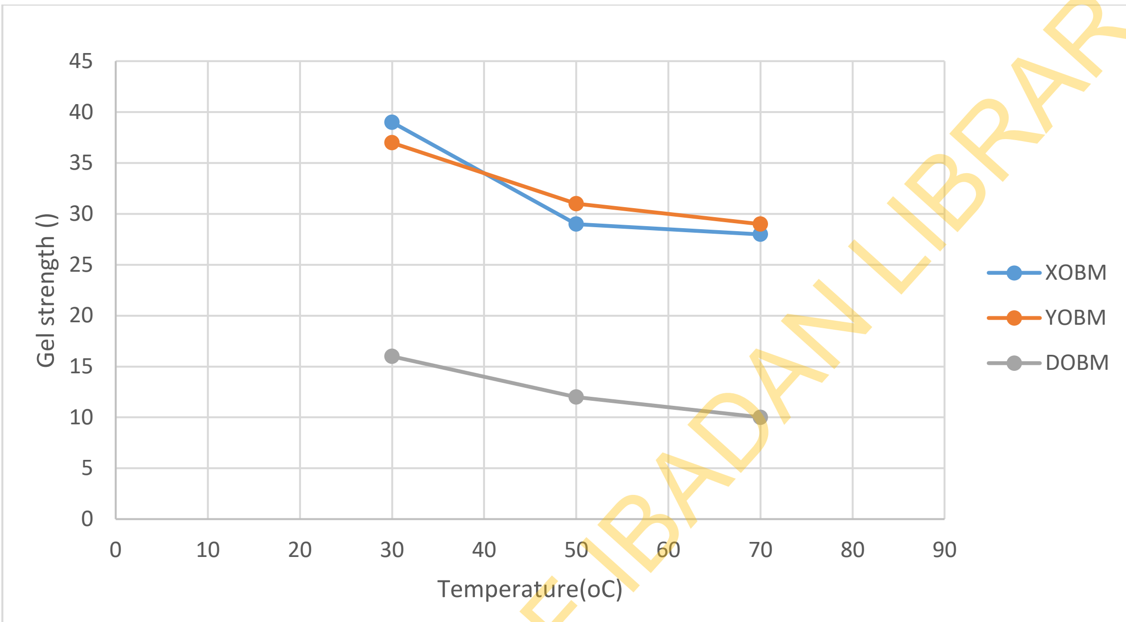


**Figure 3.0: Gel strength against Temperature ($^{o}$C) for X OBM, Y OBM and DOBM**

## FILTRATION

From the Figure 4.0, Y OBM possesses the highest fluid loss values followed by diesel OBM and X OBM. This means that Y OBM has a higher tendency to form a porous and thick filter cake compared.

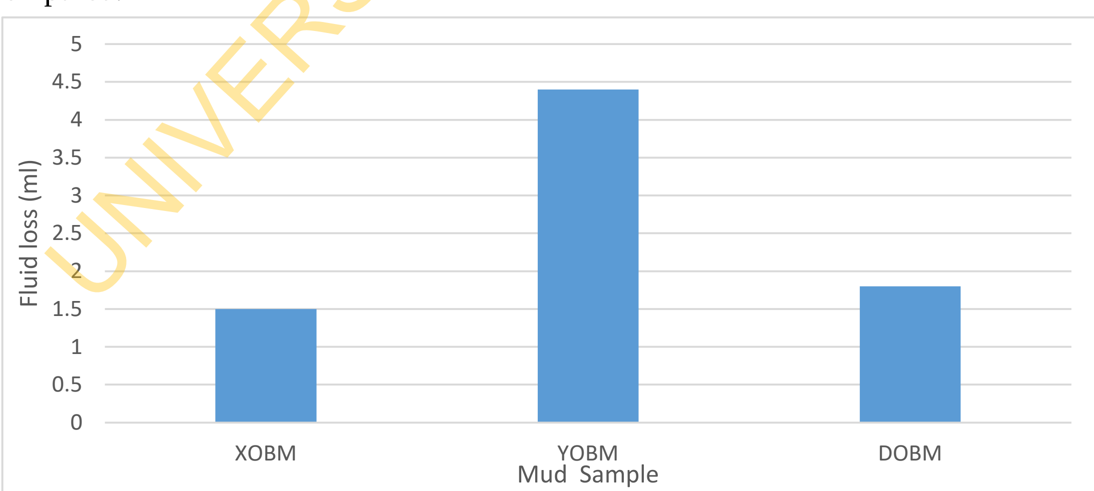

**Figure 4.0: Fluid loss(ml) at 30mins for X OBM, Y OBM and DOBM**

**Economic Analysis:**

The required mud and cuttings generated volume were determined using the equations 7.0 and 8.0, respectively, and the result presented in the Table 4.0
Assuming an oil solid water ratio of 70:20:10

**Table 4.0: Mud Volume and Volume of Cuttings Generated for the Intermediate and Production Zone**

| Casing Zone | Mud Volume (barrels) | Volume of Cuttings Generated (barrels) |
|---|---|---|
| **Intermediate Zone** | 383.0 | 1094.0 |
| **Production Zone** | 163.0 | 187 .0 |
| **Total** | 546.0 | 1281.0 |

**Cost Requirements**

The cost required was calculated using the equation 9.0 and the result for each oil is as shown in the Table 5.0

**Table 5.0**: **Oil cost per barrel ($), Cost requirement, ($) and Total Well cost, ($)**

| OBM | Oil Cost per barrel ($) | Cost Requirements ($) | Total Well Cost ($) |
|---|---|---|---|
| **Y** | 190.80 | 98,505.60 | 14,436,395.60 |
| X | 166.95 | 89,395.00 | $14,427,285.00 |
| **D** | 103.75 | 129,302.50, | 14,467,192.50 |

**NET PRESENT VALUE (NPV) PROFILE**

**Operational parameters:**

Nominal production decline rate = 17% per year
Initial production = 500 barrels per day
**Cost and Fiscal parameters:**
Operating cost = $10 per barrel
Oil price = $40 per barrel
Discount rate = 10% per annum
Depreciation = 5 years (straight line method)
Investment split (Tangible: Intangible) = 70:30

The NPV models of the use of Y, X and D OBMs. in drilling a well in the AB1 foothills of the Alberta region in Canada is presented in the Appendix A, B and C. From the results, it is observed that the use of X OBM gave the most returns as it has the least well cost requirements and the highest NPV (Figure 1.0) this is followed by Y OBM and DOBM. The Net Present Value models of the use of Y, X, and diesel OBMs, are presented in the Appendices A, B and C, respectively. For drilling a well in the AB1 foothills of the Alberta region in Canada. From the NPV, it can be observed that the use of X OBM gives the most returns of the three mud systems as it has the least well cost requirements. Based on the

NPV values from the Figure 1.0, X OBM has the highest NPV followed by Y OBM and DOBM. Based on the discounted profit ratio Figure, (Figure 2.0), the use of X OBM gives a better investment result as more is obtained on each unit of the investment compared to when using either diesel OBM or Y OBM.

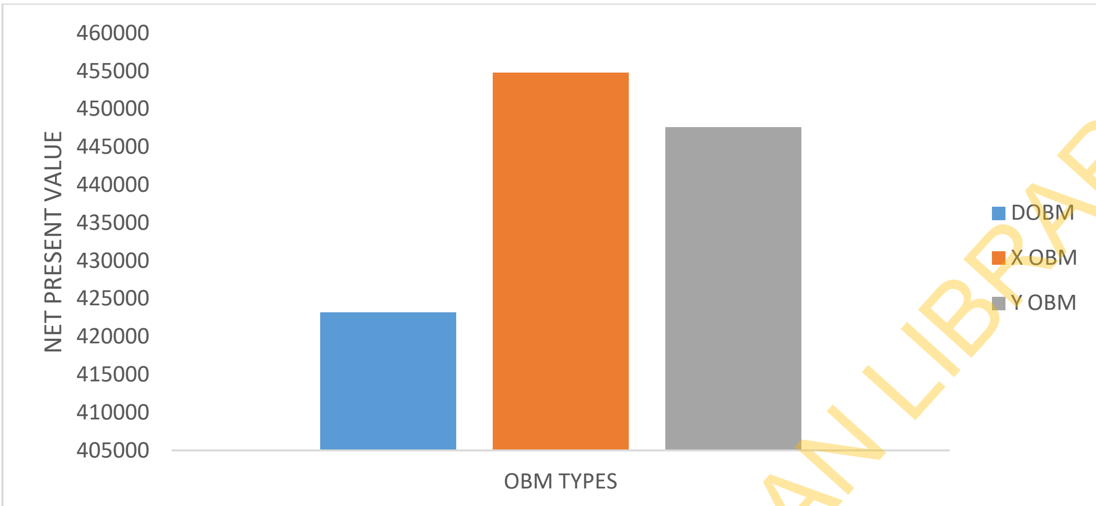


**Figure 5.0: NPV profile for Y OBM, X OBM and D OBM**

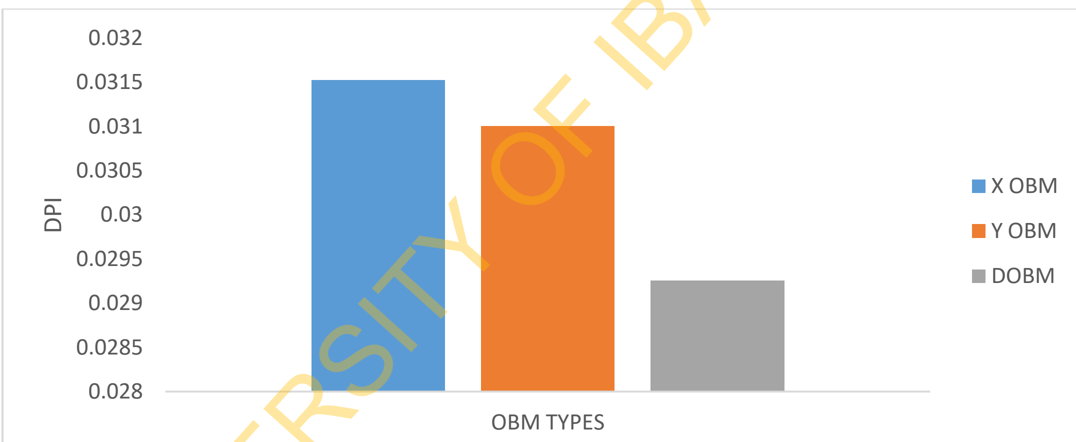


**Figure 6.0: DPI values for Y OBM, X OBM and D OBM**

**Conclusion**

From the results obtained, it was observed that the vegetable oils X and Y have the potential to be used to substitute for No. 2 diesel as base fluid in oil base mud. Although the costs of the use of the vegetable oils X and Y is higher, it will be offset when considering the cost of containment, hauling, and disposal of No. 2 diesel OBM after use. From the results of the economic analysis, it shows that the use of the X OBM has the greatest comparative cost advantage to the other mud systems, it also gives a better projected Net Present Value (NPV) and the best discounted profit to investment ratio.

**Recommendations**

The use of drilling fluid formulated from local materials would not only eradicate the problem arising from pollution but also provide a long-lasting socio-economic effect such as wealth and job creation, improvement on the relationship between the agricultural and energy sectors and also increase the nation's GDP

**Where:**

*I* = initial investment.

t = time (years)

$CF_t$ = Net cash flow for each year (i.e. income less costs)

d = drill pipe id (inches)

D = Depth (feet),

$\Phi$ = formation porosity

**Appendix A**

| Year | Daily Production | Annual production | Oil Price | Gross Annual Revenue | Royalty $ | Net Revenue |
|---|---|---|---|---|---|---|
| 0 | | 0 | 40 | 0.00 | 0.00 | 0.00 |
| 1 | 500.00 | 182500 | 40 | 7300000.00 | 1350500.00 | 5949500.00 |
| 2 | 415.00 | 166506.04 | 40 | 6660241.56 | 1232144.69 | 5428096.87 |
| 3 | 344.45 | 138200.01 | 40 | 5528000.49 | 1022680.09 | 4505320.40 |
| 4 | 285.89 | 114706.01 | 40 | 4588240.41 | 848824.48 | 3739415.93 |
| 5 | 237.29 | 95205.988 | 40 | 3808239.54 | 704524.31 | 3103715.22 |
| 6 | 196.95 | 79020.97 | 40 | 3160838.82 | 584755.18 | 2576083.64 |
| 7 | 163.47 | 65587.405 | 40 | 2623496.22 | 485346.80 | 2138149.42 |
| 8 | 135.68 | 54437.547 | 40 | 2177501.86 | 402837.84 | 1774664.02 |
| 9 | 112.61 | 45183.164 | 40 | 1807326.54 | 334355.41 | 1472971.13 |
| 10 | 93.47 | 37502.026 | 40 | 1500081.03 | 277514.99 | 1222566.04 |
| 11 | 77.58 | 31126.681 | 40 | 1245067.26 | 230337.44 | 1014729.81 |
| 12 | 64.39 | 25835.146 | 40 | 1033405.82 | 191180.08 | 842225.75 |

| Intangible Investment | Tangible Investment | Total Investment | Depreciation | Operating Cost, $/bbl | Annual Operating Expense |
|---|---|---|---|---|---|
| 4330909.05 | 10105454.46 | 14436363.51 | | 10 | 0.00 |
| | | | 2021090.89 | 10 | 1825000.00 |
| | | | 2021090.89 | 10 | 1665060.39 |
| | | | 2021090.89 | 10 | 1382000.12 |
| | | | 2021090.89 | 10 | 1147060.10 |
| | | | 2021090.89 | 10 | 952059.88 |
| | | | | 10 | 790209.70 |
| | | | | 10 | 655874.05 |
| | | | | 10 | 544375.47 |
| | | | | 10 | 451831.64 |
| | | | | 10 | 375020.26 |
| | | | | 10 | 311266.81 |
| | | | | 10 | 258351.46 |

| Before Tax Income | Tax | After Tax Income | Net Flow Cash | Cumulative Net Flow Cash | DCF @ 10 % | NPV @ 10 % |
|---|---|---|---|---|---|---|
| -4330909.05 | -1082727.26 | -3248181.79 | -13353636 | -13353636.2 | -13353636.25 | |
| 2103409.11 | 525852.28 | 1577556.83 | 3598647.72 | -9754988.52 | 3271497.93 | |
| 1741945.59 | 435486.40 | 1306459.19 | 3327550.08 | -6427438.44 | 2750041.391 | |
| 1102229.39 | 275557.35 | 826672.04 | 2847762.93 | -3579675.51 | 2139566.44 | |
| 571264.94 | 142816.23 | 428448.70 | 2449539.6 | -1130135.91 | 1673068.504 | |
| 130564.45 | 32641.11 | 97923.34 | 2119014.23 | 988878.315 | 1315741.118 | 447595.0263 |
| 1785873.93 | 446468.48 | 1339405.45 | 1339405.45 | 2328283.76 | 756059.4577 | |
| 1482275.36 | 370568.84 | 1111706.52 | 1111706.52 | 3439990.29 | 570481.2272 | |
| 1230288.55 | 307572.14 | 922716.41 | 922716.414 | 4362706.7 | 430454.0169 | |
| 1021139.50 | 255284.87 | 765854.62 | 765854.623 | 5128561.32 | 324797.1218 | |
| 847545.78 | 211886.45 | 635659.34 | 635659.337 | 5764220.66 | 245074.1919 | |
| 703463.00 | 175865.75 | 527597.25 | 527597.25 | 6291817.91 | 184919.6175 | |
| 583874.29 | 145968.57 | 437905.72 | 437905.718 | 6729723.63 | 139530.2569 | |

**Appendix B**

| Year | Daily Production | Annual production | Oil Price | Gross Annual Revenue | Royalty $ | Net Revenue |
|---|---|---|---|---|---|---|
| 0 | | 0 | 40 | 0.00 | 0.00 | 0.00 |
| 1 | 500.00 | 182500 | 40 | 7300000.00 | 1350500.00 | 5949500.00 |
| 2 | 415.00 | 166506.04 | 40 | 6660241.56 | 1232144.69 | 5428096.87 |
| 3 | 344.45 | 138200.01 | 40 | 5528000.49 | 1022680.09 | 4505320.40 |
| 4 | 285.89 | 114706.01 | 40 | 4588240.41 | 848824.48 | 3739415.93 |
| 5 | 237.29 | 95205.988 | 40 | 3808239.54 | 704524.31 | 3103715.22 |
| 6 | 196.95 | 79020.97 | 40 | 3160838.82 | 584755.18 | 2576083.64 |
| 7 | 163.47 | 65587.405 | 40 | 2623496.22 | 485346.80 | 2138149.42 |
| 8 | 135.68 | 54437.547 | 40 | 2177501.86 | 402837.84 | 1774664.02 |
| 9 | 112.61 | 45183.164 | 40 | 1807326.54 | 334355.41 | 1472971.13 |
| 10 | 93.47 | 37502.026 | 40 | 1500081.03 | 277514.99 | 1222566.04 |
| 11 | 77.58 | 31126.681 | 40 | 1245067.26 | 230337.44 | 1014729.81 |
| 12 | 64.39 | 25835.146 | 40 | 1033405.82 | 191180.08 | 842225.75 |

| Intangible Investment | Tangible Investment | Total Investment | Depreciation | Operating Cost $ / bbl | Annual Operating Expense |
|---|---|---|---|---|---|
| 4328176.71 | 10099078. | 14427255.69 | | 10 | 0.00 |
| | | | 2019815.80 | 10 | 1825000.00 |
| | | | 2019815.80 | 10 | 1665060.39 |
| | | | 2019815.80 | 10 | 1382000.12 |
| | | | 2019815.80 | 10 | 1147060.10 |
| | | | 2019815.80 | 10 | 952059.88 |
| | | | | 10 | 790209.70 |
| | | | | 10 | 655874.05 |
| | | | | 10 | 544375.47 |
| | | | | 10 | 451831.64 |
| | | | | 10 | 375020.26 |
| | | | | 10 | 311266.81 |
| | | | | 10 | 258351.46 |

| Before Tax Income | Tax | After Tax Income | Net Flow Cash | Cumulative Net Flow Cash | DCF @ 10 % | NPV @ 10 % |
|---|---|---|---|---|---|---|
| -4328176.71 | -1082044.18 | -3246132.53 | -13345212 | -13345211.5 | -13345211.51 | |
| 2104684.20 | 526171.05 | 1578513.15 | 3598328.95 | -9746882.56 | 3271208.136 | |
| 1743220.68 | 435805.17 | 1307415.51 | 3327231.31 | -6419651.26 | 2749777.941 | |
| 1103504.48 | 275876.12 | 827628.36 | 2847444.16 | -3572207.1 | 2139326.941 | |
| 572540.03 | 143135.01 | 429405.03 | 2449220.82 | -1122986.28 | 1672850.777 | |
| 131839.54 | 32959.89 | 98879.66 | 2118695.45 | 995709.178 | 1315543.184 | 454811.3546 |
| 1785873.93 | 446468.48 | 1339405.45 | 1339405.45 | 2335114.63 | 756059.4577 | |
| 1482275.36 | 370568.84 | 1111706.52 | 1111706.52 | 3446821.15 | 570481.2272 | |
| 1230288.55 | 307572.14 | 922716.41 | 922716.414 | 4369537.56 | 430454.0169 | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1021139.50 | 255284.87 | 765854.62 | 765854.623 | 5135392.19 | 324797.1218 | |
| 847545.78 | 211886.45 | 635659.34 | 635659.337 | 5771051.52 | 245074.1919 | |
| 703463.00 | 175865.75 | 527597.25 | 527597.25 | 6298648.77 | 184919.6175 | |
| 583874.29 | 145968.57 | 437905.72 | 437905.718 | 6736554.49 | 139530.2569 | |

**Appendix C**

| **Year** | **Daily production** | **Annual production** | **Oil Price** | **Gross Annual Revenue** | **Royalty $** | **Net Revenue** |
|---|---|---|---|---|---|---|
| 0 | | 0 | 40 | 0.00 | 0.00 | 0.00 |
| 1 | 500.00 | 182500 | 40 | 7300000.00 | 1350500.00 | 5949500.00 |
| 2 | 415.00 | 166506.04 | 40 | 6660241.56 | 1232144.69 | 5428096.87 |
| 3 | 344.45 | 138200.01 | 40 | 5528000.49 | 1022680.09 | 4505320.40 |
| 4 | 285.89 | 114706.01 | 40 | 4588240.41 | 848824.48 | 3739415.93 |
| 5 | 237.29 | 95205.988 | 40 | 3808239.54 | 704524.31 | 3103715.22 |
| 6 | 196.95 | 79020.97 | 40 | 3160838.82 | 584755.18 | 2576083.64 |
| 7 | 163.47 | 65587.405 | 40 | 2623496.22 | 485346.80 | 2138149.42 |
| 8 | 135.68 | 54437.547 | 40 | 2177501.86 | 402837.84 | 1774664.02 |
| 9 | 112.61 | 45183.164 | 40 | 1807326.54 | 334355.41 | 1472971.13 |
| 10 | 93.47 | 37502.026 | 40 | 1500081.03 | 277514.99 | 1222566.04 |
| 11 | 77.58 | 31126.681 | 40 | 1245067.26 | 230337.44 | 1014729.81 |
| 12 | 64.39 | 25835.146 | 40 | 1033405.82 | 191180.08 | 842225.75 |

| **Intangible Investment** | **Tangible Investment** | **Total Investment** | **Depreciation** | **Operating Cost, $/bbl** | **Annual Operating Expense** |
|---|---|---|---|---|---|
| 4340144.44 | 10127003.70 | 14467148.14 | | 10 | 0.00 |
| | | | 2025400.74 | 10 | 1825000.00 |
| | | | 2025400.74 | 10 | 1665060.39 |
| | | | 2025400.74 | 10 | 1382000.12 |
| | | | 2025400.74 | 10 | 1147060.10 |
| | | | 2025400.74 | 10 | 952059.88 |
| | | | | 10 | 790209.70 |
| | | | | 10 | 655874.05 |
| | | | | 10 | 544375.47 |
| | | | | 10 | 451831.64 |
| | | | | 10 | 375020.26 |
| | | | | 10 | 311266.81 |
| | | | | 10 | 258351.46 |
| | | | | | |

| **Before Tax Income** | **Tax** | **After Tax Income** | **Net Flow Cash** | **Cumulative Net Flow Cash** | **DCF @ 10 %** | **NPV @ 10 %** |
|---|---|---|---|---|---|---|
| -4340144.44 | -1085036.11 | -3255108.33 | -13382112 | -13382112 | -13382112.03 | |
| 2099099.26 | 524774.82 | 1574324.45 | 3599725.18 | -9782386.84 | 3272477.441 | |
| 1737635.74 | 434408.94 | 1303226.81 | 3328627.54 | -6453759.3 | 2750931.855 | |
| 1097919.54 | 274479.88 | 823439.65 | 2848840.39 | -3604918.9 | 2140375.953 | |
| 566955.09 | 141738.77 | 425216.32 | 2450617.06 | -1154301.85 | 1673804.425 | |
| 126254.60 | 31563.65 | 94690.95 | 2120091.69 | 965789.844 | 1316410.137 | 423203.6738 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1785873.93 | 446468.48 | 1339405.45 | 1339405.45 | 2305195.29 | 756059.4577 | |
| 1482275.36 | 370568.84 | 1111706.52 | 1111706.52 | 3416901.82 | 570481.2272 | |
| 1230288.55 | 307572.14 | 922716.41 | 922716.414 | 4339618.23 | 430454.0169 | |
| 1021139.50 | 255284.87 | 765854.62 | 765854.623 | 5105472.85 | 324797.1218 | |
| 847545.78 | 211886.45 | 635659.34 | 635659.337 | 5741132.19 | 245074.1919 | |
| 703463.00 | 175865.75 | 527597.25 | 527597.25 | 6268729.44 | 184919.6175 | |
| 583874.29 | 145968.57 | 437905.72 | 437905.718 | 6706635.16 | 139530.2569 | |