Effect of Synthesized Biodiesel on the Rheological Properties of Oil Based Drilling Mud

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Sheeraz Ahmed Soomro[1], Dr. Suhail Ahmed Soomro[2], Dr. Khan Muhammad Brohi[3]

[1]*Institute of Petroleum & N. Gas Engineering, Mehran University of Engineering & Technology, Jamshoro.*
[2]*Department of Chemical Engineering, Mehran University of Engineering & Technology, Jamshoro*
[3]*Institute of Environmental Engineering & Management, Mehran University of Engineering & Technology, Jamshoro.*

Abstract: Drilling the oil & gas well is the first footstep in the success of petroleum exploration & production activities which also includes blending and utilizing drilling fluids which must be safe to use, economically viable and must satisfy technical parameters. Diesel oil based muds are toxic for environment as well as nuisance for eco system. The goal of this research is to formulate the Biodiesel based drilling mud especially for shale formation which must not harm environment as well as performs as good as conventional diesel based mud. Biodiesel was extracted from Canola oil in the laboratory through Transesterification process. Two oil based mud samples were made. One sample having Biodiesel as base fluid and other containing diesel as base fluid. Quality tests of base fuels such as flash point, density and viscosity confirmed that biodiesel has better results than diesel oil. Rheological properties such as gel strength yield point etc. using Rotational Viscometer at two different temperatures i.e. 60^{o}c and 100^{o}c of both samples were measured. Results showed that biodiesel based mud demonstrated stable and much enhanced properties than diesel based mud samples. Biodiesel based mud performed better than diesel based mud as plastic viscosity, apparent viscosity, gel strength, yield point, gel 10 minutes and 10 seconds and at different RPMs and at higher temperatures was best suited for mud to be used in shale formations. Economic analysis illustrated that although initial cost of Biodiesel is higher than diesel but when it comes to disposal options; biodiesel has less disposal cost than diesel based muds hence proving biodiesel based mud as best alternate of diesel based muds in shale formation.

Keywords: *Drilling, oil based drilling mud, environment, transesterification, biodiesel, diesel, rheology.*

1. Introduction

With the rapid development of drilling technology, whole drilling process is becoming more difficult and the also harsher operational environments. Water-based drilling fluids (WBDFs) have limited ability for countering the complicated situations. An oil-based drilling fluid (OBDFs) provides several advantages like stability of the hole, exceptional lubricity, and reduced chances of stuck pipe. For these reasons, operators prefer using OBDFs for highly difficult drilling and certain formations which are sensitive to water like shale formations.[1] However, conventional OBDFs (diesel-based) have certain downsides like their high overall cost, and the other is their negative effects on the ecosystem. Since many years, due to stricter laws and regulations by the governments, industry limited the utilization of conventional OBDFs sharply. To counter this issue, biodiesel based drilling fluids (BBDF) were developed. BBDF performs as good as conventional oil based mud even sometimes better than them and also biggest advantage is they are biodegradable & are less toxic.[2]

In some regions, BBDF can be disposed of without any additional treatment, that is very significant for offshore drilling.[3] However, biodiesel is normally costly in comparison to conventional diesel. High price tag limits the progress of BBDF, but comparing the disposal cost of OBDFs as it requires special procedures, the cost of BBDFs comes under the budget. Biodiesel is a substitute to mineral oil diesel which is produced from renewable resources such as animal fats, plant oils and many recycled oils.[4] The prominent mixtures in biodiesels are known as fatty acid methyl esters (FAME), which are transformed from triglycerides in a chemical reaction known as transesterification. Biodiesel can function as a base fluid for drilling fluids in place of diesel and can efficiently replace diesel as base fuel as it contains all the benefits of petroleum based diesel. Biodiesel has the advantage of being renewable. Moreover, it can be more economical, if the biodiesel manufactured from waste cooking oil can be used as the base fluid of drilling fluid. In recent times, the biodiesel production increased globally .[5] Due to increase in production, it will affect the cost as cost will be reduced to some extent. It’s also a fact that biodiesel cannot substitute petrodiesel entirely yet. Thus, utilizing biodiesel as a base fuel in the drilling mud will provide an economical working fluid for drilling engineers and also enhance the use of biodiesel.

2. Related Work

The study conducted for different biodiesel oil based muds to check physical properties and biodegradation rate of biodiesel based drilling fluids with respect to its toxicity and compare with the conventional oil based drilling fluids particularly in marine environment which endorses that vegetable oils were more nontoxic and biodegradable than conventional petroleum diesel in the marine environment.[6] Jatropha and groundnut oil biodiesel was tested to be used as a base fluid in oil based mud. Samples made from jatropha, groundnut oil biodiesel showed that vegetable oil biodiesels showed more

Corresponding author Email address*: shiraz_soomro92@hotmail.com*

enhanced and optimistic results than diesel oil based mud in particular conditions.[7] Economic analysis between conventional petroleum based diesel and seven local vegetable oils showed that the average cost percent of savings on the use of the seven local vegetable oils over the use of commercial petro diesel offshore and onshore were nearly 50% hence proving biodiesel to be more economical.[8]

3. Methodology

3.1 Production of Biodiesel from Canola Oil

Canola oil was used for the formulation of OBDFs for this research. Biodiesel was produced through Transesterification in the laboratory. For preparation of 1.5 liter biodiesel, 400 ml methanol, 8 grams of KOH and 1.5 liter pure Canola oil was used. It is so much important that during reaction, the oil and methanol is slightly warm for a better reaction. So, 50^{o}c temperature was provided to canola oil for better mixing of oil and alcohol-catalyst mixture.

3.2 Quality tests of Diesel & Biodiesel

Quality tests for both base fuels i.e. diesel and biodiesel were conducted to assess the performances of both base fuels. For this purpose, flash point, density and viscosity tests were conducted in the laboratory using Open Cup Flash Point apparatus for the flash point, Pycnometer for the density and Saybolt Viscometer for the Kinematic Viscosity.

3.3 Formulation of Oil Based Mud Samples

Two Oil Based Mud (OBM) samples were prepared having diesel and biodiesel as base fluids. Two commonly used additives i.e. Barite and Bentonite for formulation of conventional OBM were selected. Quantities of additives were kept constant for both samples. The quantity of additives and quantity of oil and water is given in the Table 1:

Table 1: Depiction of quantity of additives used in samples

	Diesel Based Mud	Biodiesel Based Mud
Oil (ml.)	420	420
Water (ml.)	105	105
Barite (gm.)	80	80
Bentonite (gm.)	12	12

3.4 Rheology Test

The rheological test was then accomplished by means of Rotational Viscometer to find the plastic viscosity (PV), apparent viscosity (AP), yield point (YP) and gel strength of the mud samples. Yield Point (YP) is the stress required to move drilling fluid. It is used to determine the ability of mud to lift cuttings out of the annulus. Plastic viscosity (PV) is a measurement of resistance of fluid to flow. For PV and YP analysis, the sample was stirred at 600 rpm. The reading was stabilized at 600 rpm before proceed to 200, 100, 6 and 3 rpm speed respectively. The results from viscometer reading were used to measure PV, AP and YP value using Eq. 1, Eq. 2 & Eq.3.

Plastic viscosity in Centipoises = 600 RPM – 300 RPM………. (1)

Apparent viscosity in Centipoises = 600 RPM/2………. (2)

Yield Point, (lb/100ft2) = PV – Reading at 300rpm………. (3)

Gel strength was measured at time 10 seconds and 10 minutes. It is the shear stress of drilling mud that is measured at low shear rate after the mud had been static for certain time period. The properties are important to investigate the ability of drilling mud to suspend cuttings and weighting material when circulation is stopped. For gel strength analysis, the sample was stirred at 600 rpm for 30 seconds before taking 10-second gel strength at 3 rpm. The mud was stirred again at 600 rpm and let it undisturbed for 10 minutes. Then, the gel strength reading for 10 minutes was taken at 3 rpm.[9]

3.5 Cost Comparison

Cost analysis in this research work has been done for the basic but important parameters like the cost of additives used in this research work, cost of base oil and total cost of formulation of drilling fluid/barrel. Furthermore, additional cost analysis is done for the management and disposal of the diesel based and biodiesel based drilling fluid to evaluate the difference of cost between both base fuels and how it will impact the overall economics of the particular well drilled. The information required for the cost analysis was obtained from the industry staff, published literature sources and from the local market.

4. Results and Discussion

4.1 Biodiesel

After Transesterification process, when the samples were left for separation of biodiesel and glycerin, two phases were separated due to gravity effect as the fluid in lower phase having brown colour is glycerin and the fluid in the upper phase having light yellowish colour is Biodiesel. Both phases were separated and the final product (Biodiesel) was ready.

4.2 Flash Point

Flash point is the lowest temperature at or above which vapors of that liquid will ignite when provided an ignition source. This test was conducted on Cleveland open cup flash point tester. The flash point of both fuels is given in the Table 2:

Table 2: Flash point of Diesel & Biodiesel

Fuel	**Diesel**	**Biodiesel**
Flash Point	72^{o}c	160^{o}c

As, flash point is directly linked to safe handling and storage of fuels, so, higher flash point fuels are most favorable for use in high temperature zones. As we are using the biodiesel for formulation of OBDF and there are very high temperatures in the subsurface also higher flash point fuel will provide ease to the industry to store it in the areas which are high temperature zones. So, biodiesel is favorable to use in this regard due to higher flash point.

4.3 Density

Density is defined as mass per unit volume. According to the results, the density of both fuels is shown in Table 3:

Table 3: Density of Diesel & Biodiesel

Fuel	Diesel	Biodiesel
Density	0.84 g/ml	0.89 g/ml

Here it can be seen that there is not much difference in densities between both fuels. However, fuels with high density are usually favorable to be used for drilling fluids formulations.

4.4 Viscosity

Viscosity test has its own importance because it affects the performance when the fuel is used for the drilling fluid. Equipment used for viscosity determination was Saybolt Viscometer. The viscosity of Biodiesel & Diesel is shown in the Table 4:

Table 4: Viscosity of Diesel & Biodiesel

Fuel	Diesel	Biodiesel
Viscosity (at 40ºc)	2.86 mm^2/s	4.72 mm^2/s

Usually, fuels with higher viscosities are not considered favorable for engines because of the poor combustion but we are not using fuel for engine here. We are using for the formulation of OBDFs. So, in this context, base fuels with higher viscosities are favorable as it will reduce the amount of additives we use to increase viscosity hence saving huge costs of additives to the industry.

4.4 Rheology Test Outcomes

After the quality tests conducted, drilling fluid was formulated from the both fuels with same quantity of additives and testing at two different temperatures. The Table 5 shows the different viscometer readings at different RPM of Rotational Viscometer at two different temperatures i.e. 60 and 100. The viscosity values decreases immediately due to increase in temperature. This creates problems for the engineers when drilling in deep formations and especially in High Pressure High Temperature (HPHT) wells.

Table 5: Variations of viscosity with different temperatures and viscometer readings for Diesel based drilling fluid

Viscometer Dial Setting RPM	Viscosity at 60ºc	Viscosity at 100ºc
600	40	35
300	32	28
200	25	23
100	19	18
60	16	15
30	14	12
6	13	11
Gel 10 Sec	11	8
Gel 10 Min	14	9
Plastic Viscosity	8	7
Apparent Viscosity	20	18
Yield Point	24	21

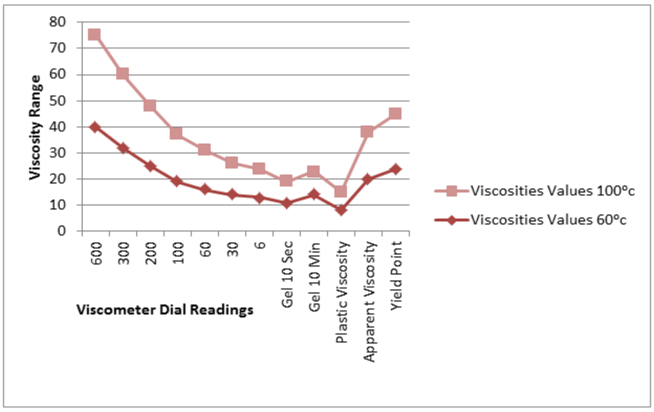

Figure 1: Graph for the viscometer readings for Diesel based drilling fluid

Viscosity reading of Biodiesel based mud is shown in Table 6. The viscosity at all RPMs shows more stability than diesel based mud. Even at high temperature at 100ºc, the viscosities are far more stable than diesel based mud that can give the advantage to industry to drill in HPHT wells easily. Plastic viscosity, apparent viscosity, yield point and gelling at 10 seconds and 10 min also showed far better results than conventional diesel.

Table 6: Variations of viscosity with different temperatures and viscometer readings for Biodiesel based drilling fluid

Viscometer Dial Setting RPM	Viscosity at 60ºc	Viscosity at 100ºc
600	90	74
300	66	55
200	48	46
100	37	39
60	25	23
30	17	14
6	10	8
Gel 10 Sec	9	5
Gel 10 Min	9	6
Plastic Viscosity	24	19
Apparent Viscosity	45	37
Yield Point	42	36

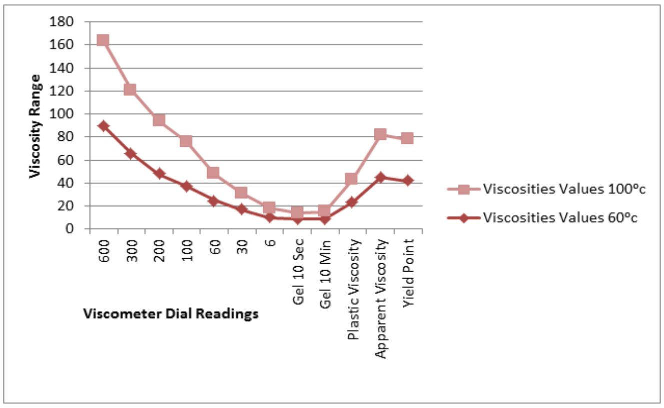

Figure 2: Graph for the viscometer readings for Biodiesel based drilling fluid

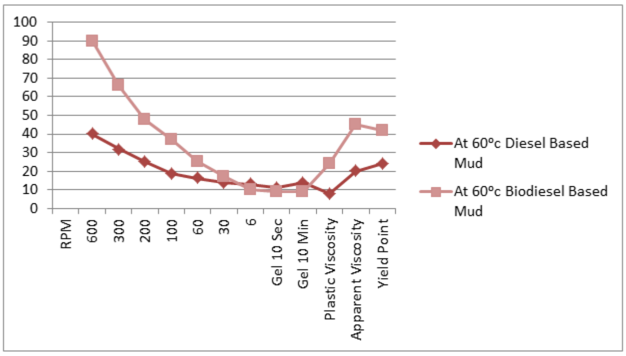

Figure 3: Viscosity comparison of Diesel Based Mud & Biodiesel Based Mud at 60°c

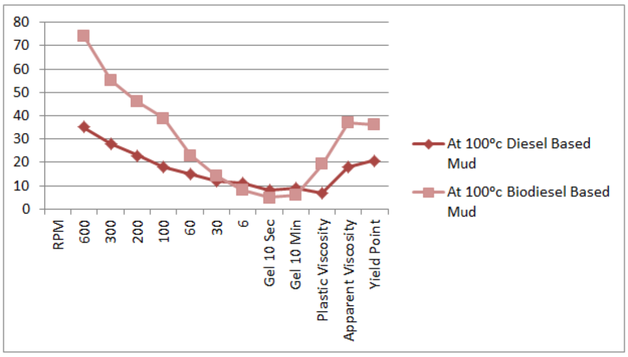

Figure 4: Viscosity comparison of Diesel Based Mud & Biodiesel Based Mud at 100°c

Figure 3 shows the rheological properties of Diesel and Biodiesel based muds at 60°c. At same temperature, Biodiesel based mud has way better viscosity than diesel mud and also in Figure 4, at 100°c, Biodiesel based mud surpasses diesel based mud that shows superiority of Biodiesel to conventional diesel.

4.5 Impact Of Base Fuels On Rheological Properties

Viscosities of petroleum diesel and biodiesel based muds at different temperatures were noticed. It was observed that viscosities of biodiesel based muds were far more than diesel oil based muds. Even at higher temperature i.e., 100°c, the viscosity of biodiesel mud at all oil water ratios was higher and more stable than diesel muds.

Mud with high gel strength is not favorable in drilling operations as it requires high pumping pressure in order to break circulation after the mud is static for long period. The required 10 minutes gel strength is typically less than 20 lb./100ft^2 in which the both muds passed the limits. As, biodiesel mud system satisfies other parameters successfully so we can say that in biodiesel mud system, gel strength is also under favorable limits as excessive gel strength may increase the swabbing and surging effect during tripping process of drill pipe.

Yield point is used to determine the ability of mud to lift cuttings out of the annulus. The mud with high yield point can carry cuttings better than mud with similar density but lower yield point. The results shows that yield point value of biodiesel mud system was higher than diesel based mud system that gives advantage of better cutting carrying capacity from the biodiesel based mud.

4.6 Impact of Temperature

When the well is drilled, engineers need the robust kind of materials and drilling fluid to withstand high temperatures as often the viscosity of drilling fluid decreases significantly with rising temperatures. Due to this the mud destabilizes and causes problems for engineers to complete the operations.

As, the above graphs of effect of temperature on mud viscosity shows biodiesel muds exhibits stable conditions than diesel based muds.

It is clear that in temperature comparisons, biodiesel based mud having performs well in extreme temperature conditions causing mud stability and hence reducing the problems for engineers after encountering high temperature zones particularly in the shale formations.

4.7 Cost Comparison of Formulation & Disposal

The actual cost of the drilling fluids depends on the cost of many factors and operations of drilling fluids like the prices of base oil and additives used in the particular drilling fluid, cost of maintaining mud properties, cost of making available excess mud volumes to tackle the downhole problems, depth of the hole to be drilled, drilling fluid consumption and many other factors.[10] So, combining these all factors collectively the economic analysis is done for the optimum biodiesel based mud compared to diesel based mud used in the industry with basic additives. The cost of formulation of diesel and biodiesel based mud is given in Table 7:

Table 7: Comparison of cost of formulation of diesel and biodiesel based fluids

	Biodiesel	Diesel
Cost of oil/bbl ($)	93.8	72.3
Cost of additives ($)	64.5	64.5
Total Cost ($)	158.3	136.8

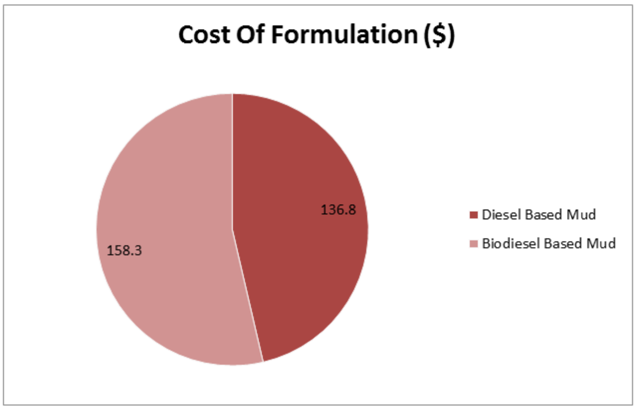

Fig 4: Graphical representation of cost of formulation of diesel and biodiesel based muds

Drilling fluid is reused until the completion of the drilling process of a particular well. However, upon completion, there is a huge responsibility of disposing of the drilling fluid. Disposal methods can vary from operator to operator. The selection of the disposal process depends on the type and cost of treatment as well as types of cuttings generated. There are range is disposal options, some could be onsite, offsite, landfills, and thermal technologies. Saltwater sludge and oily cuttings are not appropriate for site handling. Economics is also another cause for commercial waste management facilities. Specially, oil-based mud cuttings from diesel and mineral oils pose a difficult and expensive waste management challenge and cannot be discharged on-site. Oil based mud having excessive hydrocarbons requires thermal treatment. There can be as high as $75 to $150 per ton cost of thermal treatment of waste containing oils.[8] Due to the greater health issues of Diesel oil-based muds as well as economics of the disposal and treatment, the oil industry has limited the extensive usage while putting vegetable oil-based mud as an ideal substitute. In 2010, disposal costs reported by (US Energy Information Administration) offsite commercial disposal facilities for oil-based drilling wastes ranged from $3 to $67/bbl. Most operators charge transportation cost by hour typically $68.00/hr. to $195.00/hr.[10] Others use per-load or per container basis for instance in one case $3.00/bbl to $6.00bbl. It's not possible to measure all the benefits of disposal and management of biodiesel muds economically considering the environmental benefits they offer and it's also challenging to find total cost of management of drilling from both base fuel muds.[11] With the existing numbers, contrast of the dumping price of one barrel of both the base fuel muds is shown in Table 8:

Table 8: Cost comparison of management and disposal of diesel oil based and biodiesel based muds

Cost Parameter	Diesel Oil Based Mud	Biodiesel Based Mud
Cost of transportation of drilling wastes to disposal site (US$/bbl)	5	5
Cost of Commercial disposal of drilling wastes (US$/bbl)	65	33
Cost of transportation + Disposal (US$ /bbl)	70	38
Total cost of disposal of 1barrel (US$/bbl)	70	38

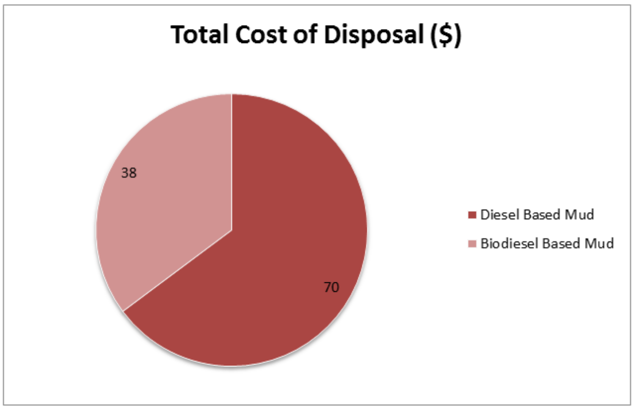

Fig 5: Total cost of disposal of diesel oil based and biodiesel based muds

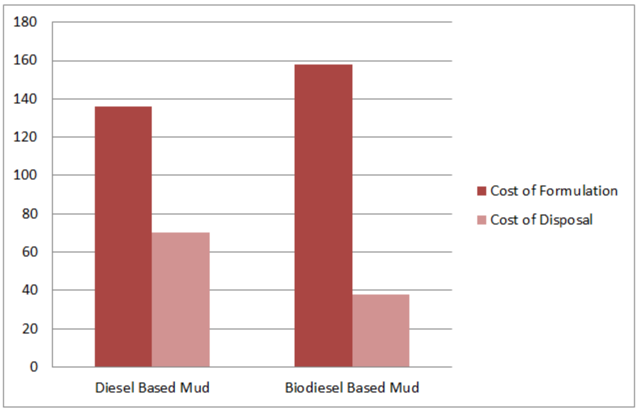

Fig 6: Total cost comparison of formulation and disposal of diesel based and biodiesel based mud

Here, the Fig. 6 indicates that the cost of formulation of Biodiesel based mud (per barrel) is slightly higher than the cost of diesel based mud but it is not that much high if we look up the consequences and impacts of diesel based fluids on the environment. Environmentalists in recent times have shown great concern in the OBDFs specially their disposal. They have a solid point of view that OBDFs can pollute water supplies if they are used offshore and they hold toxic chemicals that pose fatal threat to marine living organisms. Diesel is non-biodegradable and is more toxic due to high aromatics. So, the concern of environmentalists is justified. Even though BBDF is usually a bit higher in budget initially, the discharge of BBDF can be done on site, compared to OBDF, where most of the regulations do not permit direct discharge of OBDF. Even though if not done onsite, BBDF needs very little treatment cost compared to OBDF. This can increase the cost of drilling using OBDF. The higher cost of BBDF can be justified by its better performance compared to OBDF. Due to this reason, the disposals of diesel based muds have lot of economic viabilities as they require some specialized treatments so that environment can be protected. As, advantages of biodiesel are, that they are of domestic origin, can reduce the dependency on imported petroleum, high flash point and most important is its biodegradability. This proves that it is much beneficial to use biodiesel as base fluid than petroleum diesel.

5. Conclusion

In this paper, we compared the conventional Diesel oil based mud properties with Biodiesel based mud. Biodiesel was successfully prepared from Canola oil. Quality tests such as flash point, density and viscosity were conducted for the petroleum diesel and biodiesel. The results showed that biodiesel has slightly more favorable properties for using as a base fuel in drilling fluid. The flash point of biodiesel was higher than petroleum diesel as in high temperature zones it is favorable to have high flash point fuels for safety purpose. There was not any significant difference in densities of both fuels however, viscosity of biodiesel was high and it is favorable for drilling fluid formulation.

Two drilling fluid samples were prepared, one from diesel as base fuel and other from biodiesel as base fuel with same quantity of additives. The rheological properties showed that drilling fluid having biodiesel as base fuel have more optimistic and favorable properties as compared to diesel based fluid. The Biodiesel drilling fluid came out to be more favorable for drilling in shale formations as it performed far well than diesel based mud even at high temperature of 100°c. This gives industry the advantage of less expenditure on other additives.

Cost comparison was done for the formulation of both oil based muds which showed that although biodiesel have slightly high initial cost than diesel oil but when the cost estimation of disposal of both oil based fluids was done it was clear that diesel based fluid has high disposal cost due to its toxicity and requires some special procedures while biodiesel based mud's disposal do not have special procedures of disposal like diesel. It was proved that initial cost of BBDF may be higher but it provides ease and economical advantage over OBDF in disposal.

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References

[1] GPC, "Drilling, Completion and Workover Fluids," *World Oil*, no. 713, p. 27, 2007.

[2] W. Li *et al.*, "An investigation on environmentally friendly biodiesel-based invert emulsion drilling fluid," *J. Pet. Explor. Prod. Technol.*, vol. 6, no. 3, pp. 505–517, 2016, doi: 10.1007/s13202-015-0205-7.

[3] "BIODEGR4DABILITY OF BIODIESEL IN THE AQUATIC ENVIRONMENT Xiulin Zhang, Charles L. Peterson, Daryl Reece, Gregory Mbller, Randall Haws 1," *System*.

[4] S. Vedha Lakshmi, A. M. Aparna, and R. Baskaran, "Production of Biodiesel from Waste Cooking Oil," *5th Int. Conf. Sci. Technol. Eng. Math. ICONSTEM 2019*, vol. 3, no. 6, pp. 270–274, 2019, doi: 10.1109/ICONSTEM.2019.8918857.

[5] D. P. Heller and J. Bicerano, "Drilling fluid additive and base fluid compositions of matter containing B100 biodiesels ; and applications of such compositions of matter in well drilling , completion , and workover operations," pp. 1–15, 2016.

[6] A. R. Ismail, A. H. Alias, W. R. W. Sulaiman, M. Z. Jaafar, and I. Ismail, "Drilling fluid waste management in drilling for oil and gas wells," *Chem. Eng. Trans.*, vol. 56, pp. 1351–1356, 2017, doi: 10.3303/CET1756226.

[7] P. A. L. Anawe, V. Efeovbokhan, A. Ayoola, and O. Akpanobong, "Investigating alternatives to diesel in oil based drilling mud formulations used in the oil industry," *J. Environ. Earth Sci.*, vol. 4, no. 14, pp. 70–78, 2014.

[8] R. Amorin, A. Dosunmu, and R. K. Amankwah, "Economic Viability of the Use of Local Pseudo-Oils for Drilling Fluid Formulation," *Ghana Min. J.*, vol. 15, no. 2, pp. 81-90–90, 2015.

[9] T. S. Mihalakis, P. G. Makri, V. C. Kelessidis, G. E. Christidis, A. E. Foscolos, and C. E. Papanikolaou, "Improving Rheological and Filtration Properties of Drilling Muds with Addition of Greek Lignite," *7th Natl. Congr. Mech.*, no. 1980, pp. 1–6, 2004.

[10] O. E. Agwu, I. A. Isemin, and M. G. Akpabio, "Cost benefit analysis of vegetable oils used as alternatives to diesel in the formulation of oil-based drilling muds," *Soc. Pet. Eng. - SPE Niger. Annu. Int. Conf. Exhib. NAICE 2015*, 2015, doi: 10.2118/178265-ms.

[11] A. P. Tchameni and L. Zhao, "Effectiveness of waste vegetable oil biodiesel and soybean oil biodiesel as additive in water based mud system," *Asian Trans. Eng.*, vol. 05, no. 04, pp. 1–7, 2015.

About Authors

1. **Engr. Sheeraz Ahmed Soomro** from Mehran University of Engineering & Technology, Jamshoro completed his Bachelor of Engineering in Petroleum & Natural Gas in 2014. Currently he is doing Masters of Engineering in Environmental Engineering from Mehran UET, Jamshoro. His research interest topics includes Drilling fluids, Environmental challenges in oil industry, Biodiesel, petroleum refining, health and safety.

2. **Dr. Suhail A. Soomro** is Prof. at Chemical engineering, Mehran University of Engineering and Technology Jamshoro Sindh Pakistan. He has pursued his bachelor of engineering from Mehran UET Jamshoro Sindh Pakistan in 1989. He completed his MSc in Advanced Chemical engineering from University of Bradford, Bradford U.K in 1992. He awarded his PhD Degree in Chemical engineering from Mehran UET Jamshoro Sindh Pakistan. Prof Suhail awarded Earned Gold Medal for securing First Class First position in undergraduate Chemical. His research interest are Drilling fluid system, transmission of heavy oils, Waste Treatment & Management, Bioprocess Engineering & Bioremediation, Polymer Processing & characterization, Clean coal technology, Catalysis & Catalyst synthesis and characterization.

3. **Dr. Khan Muhammad Brohi** is currently working as Dean, Faculty of Architecture & Civil Engineering, MUET Jamshoro. He did is B.E in Mechanical Engineering from MUET, Jamshoro. He did his PhD in Environmental Engineering from Nagoya University Japan in 2002.