Economic Viability of the Use of Local Pseudo-Oils for Drilling Fluid Formulation*

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Abstract

The initial cost of formulating Synthetic Base Muds (SBM) compared to conventional Oil Base Muds (OBM) may be doubled but after considering the cost of containment, hauling, and disposal of OBM after use, the cost of using SBM becomes relatively cheaper. The formulation and disposal options (onshore and offshore) and the cost benefit of using seven local antioxidated pseudo-oils (vegetable esters) SBM compared to commercial OBM at an average offshore and onshore temperature operations were simulated in this work using API standard performance benchmarks. The average cost percent of savings on the use of the seven local vegetable oils over the use of commercial synthetic base fluid offshore and onshore were 48.32% and 56.30% respectively. Thus the use of local ester oils for drilling fluids formulation are more economical compared to currently imported oil based drilling fluids. The cultivation and production of these local pseudo-oils are on the increase guaranteeing its adoption and application to be very sustainable.

Keywords: Antioxidants, Disposals, Economics, Esters, Formulations

1 Introduction

This is a continuation of the work "Amorin, R., Dosunmu, A. and Amankwah R. K. (2015), "Enhancing the Stability of Local Vegetable Oils (Esters) for High Geothermal Drilling Applications" *Journal of Petroleum and Gas Engineering*, Vol. 6(4), pp. 10-21".

The cost for drilling a typical well may be $ 34 - 42 million when drilled without any problems (Fitzgerald *et al*., 2000). Problems in wells can quickly escalate costs dramatically especially in High Pressure High Temperature (HPHT) or hostile environments. There have been cases of such HPHT wells costing in excess of $ 68 million due to drilled hole problems. Some wells have even been lost after such significant investment due to insurmountable difficulties. The drilling fluid plays a key role in the success of such wells and must be fit for purpose (Fitzgerald *et al*., 2000).

The initial cost of formulating Synthetic Base Muds (SBMs) compared to Oil Base Mud (OBM) may be doubled (Vajargah *et al.,* 2009; Growcock and Patel, 2011) but the cost of containment, hauling, and disposal of OBMs after use are quite high compared to SBMs (Tehrani, 2007; Vajargah *et al.,* 2009). The use of cheaper local Synthetic Base Fluid (SBF) products and its allowed discharge at drilling sites offsets its initial cost of formulations, thus transportation and disposal costs are saved (Vajargah *et al.,* 2009). SBM can be used repeatedly to such an extent that major cost reductions can be achieved with minimal Non-Productive Time (NPT). The use of SBMs can reduce drilling times by 50 to 60% and well costs reduced by half (Vajargah *et al.,* 2009). An example is the use of n-alkane SBM for the Central Graben area in the UK sector of the North Sea which remained relatively problem free throughout the drilling phase of the project. This resulted in significant operational cost savings (Fitzgerald *et al*., 2000). The synthetic based drilling fluids was used for 18 months of continuous drilling in over 130 wells, using and reusing the fluids to achieve significant cost savings while still delivering highly productive wells, including the longest, most productive, onshore horizontal wells in India (Sawyer *et al.,* 2011). Generally, the net cost of using SBM is significantly less than WBMs and OBMs though their initial costs may still be higher (Growcock and Patel, 2011).

This paper considers the formulations and disposal options (onshore and offshore) and the cost benefit of using local antioxidated esters (pseudo-oils) to Commercial Synthetic Base Fluid (CSBF) for average offshore and onshore temperature operations.

1.1 Drilled Cuttings Disposal Cost Options

The primary options available for disposal of oil based drilling cuttings are either offshore or onshore discharge (Derrick, 2001; Bernier *et al.,* 2003). For offshore disposal, the cuttings (non-toxic) are discharged overboard from drilling vessels or platforms after undergoing treatment by solids control equipment or re-injected into permeable subterranean formations where drill cuttings are ground to fine particle sizes and disposed off, along with entrained non-toxic drilling base oils. For onshore disposal, the cuttings

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and the associated non-toxic oils are collected and transported for treatment (e.g. thermal desorption, land farming) if necessary and final disposal by techniques such as land filling, land spreading, injection, or re-use (Bernier *et al.,* 2003).

The onshore disposal option has the advantage that it does not leave an accumulation of cuttings and associated non aqueous drilling fluids on seafloors avoiding local impacts to the seafloor and biota. However, the onshore disposal option has several disadvantages apart from the high cost associated with the boat rental, fuel costs, ground transport, and treatment and or disposal (Bernier *et al.,* 2003).

The non-discharge disposal options offshore require equipment such as auger or vacuum systems to move cuttings from solids control equipment to offloading point or on-site injection plant (Derrick, 2001). A typical casing program may generate conservatively 159 m^3 (1 000 bbls) of cuttings when drilled with oil based or synthetic oil based muds (Derrick, 2001). The transport of these cuttings onshore may incur a cost of $ 2 500/day for rental and operation of cuttings handling equipment and $ 277/tonne of waste for transport to shore or to an alternate offshore disposal site (Derrick, 2001). Further treatment onshore may attract a cost for thermal treatment (UK) 251 $/tonne, incineration treatment (UK) 111 $/tonne, landfarm (USA) 37 $/tonne, untreated landfill (UK) 74 $/tonne, treated landfill 208 $/tonne and onshore injection 130 $/tonne (Derrick, 2001).

The discharge of cuttings offshore is the least expensive, operationally uncomplicated, and safest of the three options (Satterlee *et al*., 2011). The following are the offshore dumping restrictions (Derrick, 2001):

(i) Dumping of cuttings is prohibited if drilled with diesel or mineral oil based muds;
(ii) Dumping of cuttings drilled in ester based synthetic oil based muds that retain a maximum of 9.4% oil on cuttings by weight are permissible; and
(iii) Dumping of non-ester based synthetic oil based muds that retain a maximum of 6.9% oil on cuttings by weight; dumping are permissible offshore.

The discharge of these Non-Aqueous Fluids (NAFs) are grouped according to their aromatic hydrocarbon content and include the following (Bernier *et al*., 2003; Satterlee *et al.,* 2011):

(i) Group I NAF has polycyclic aromatic hydrocarbon (PAH) content of diesel-oil fluids typically 2 to 4% (high aromatic content). Because of concerns about toxicity, diesel-oil cuttings are not discharged. Group I NABFs are defined by having PAH levels greater than 0.35%;

(ii) Group II NAF (medium aromatic content) is known as Low Toxicity Mineral Oil Based Fluids (LTMBF). They were developed to address the concerns of the potential toxicity of diesel based fluids. The PAH content of the diesel oil fluids is reduced to less than 0.35% but greater than 0.0001%.

Group III NAF (low to negligible aromatic content) are the newest generation of drilling fluids that include highly processed mineral oils and synthetic based fluids produced by chemical reactions of relatively pure compounds and include synthetic hydrocarbons (olefins, paraffins and esters). These synthetic fluids are stable in high-temperature downhole conditions and are adaptable to deep water drilling environments. The PAH content is very low (<0.001%). They have the lowest acute toxicity and their discharges have produced far fewer effects on benthic communities than the early generation oil based mud cuttings discharges. Their effects are rarely seen beyond 228.6 to 457.2 m (750 to 1 500 ft) from the discharge. These fluids are discharged in many offshore areas such as the Gulf of Mexico, Azerbaijan, Angola, Nigeria, Equatorial Guinea, Congo, Thailand, Malaysia, Newfoundland, Australia and Indonesia.

Among the SBFs, ester based fluids or fatty acid esters (pseudo oils or plant seed oils) are known to be relatively inexpensive and environmentally friendly (Shah *et al.,* 2010). The disposal of these oils are very economical (Fig. 1).

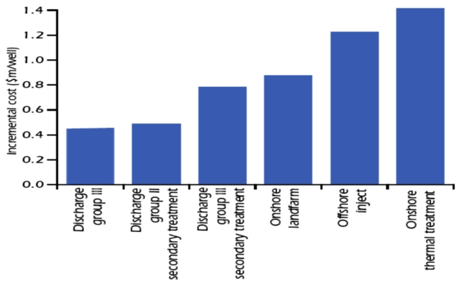

Fig. 1 Relative Costs of Disposal Options (Bernier *et al*., 2003)

The incremental drilled cuttings cost per well may range from $ 450 000 with a Group III and basic solids control equipment to $ 1 400 000 for onshore landfill disposal after thermal treatment of cuttings drilled with a Group II NADF (Fig. 1).

This work considered the cost viability of using the seven local vegetable oils over conventional base fluids such as Commercial Synthetic Base Fluid (CSBF) and Diesel Oil (DO). This considered the cost of formulations and discharge.

Most vegetable oils deteriorate rapidly in the presence of oxygen and go rancid and would require further refinery processes to obtain an API biodiesel standard because of their instabilities (Akaranta and Akaho, 2012; Okullo *et al.,* 2012). There are basically three ways of improving the stability of these oils and these can be through:

(i) Genetic modification through biotechnology to produce oils that have high saturated acid;

(ii) Chemical modifications through hydrogenation of the vegetable oil to alter the fatty acids; and

(iii) The use of antioxidants (additives).

Antioxidants happen to be the most efficient and cost effective ways to improve the oxidative stability temperatures (Aluyor and Ori-Jesu, 2008) and were therefore considered in this work.

2 Materials and Methods Used

Three antioxidants such as Propyl Gallate (PG) Citric Acid (CA) and Red Onion Skin Extract (ROSE) were added to stabilise seven local plant seed oils (pseudo-oils) namely Jatropha Oil (JO), Palm Oil (PO), Palm-Kernel Oil (PKO), Coconut Oil (CO), Soyabean Oil (SO), and Refined Waste Home-Cooking Oil (XB1000). Drilling fluids were formulated from these oil samples and compared to two formulated commercial oils namely; Diesel Oil (DO) and Commercial Synthetic Base Fluid (CSBF). The economics of the formulations are presented in Tables 1 to 3.

The cost of the oil samples were gathered from the local market in Tarkwa and Accra, Ghana. The average exchange rate used in the work was obtained from the Bank of Ghana at a rate of ₵ 3.85 = $ 1.00 as of May, 2015. Data of some other items used for the analysis were obtained from Derrick, (2001), Bernier *et al*., (2003) and Anon. (2015). Calcium chloride, primary and secondary emulsifier, wetting agent, fluid loss additive, are not shown in the cost analysis because the same amount (quantity) were administered in all formulations.

An assumed 159 m^3 (1 000 bbls) of mud samples were formulated for each sample with corresponding generation of 1 000 waste materials (cuttings) or contaminated fluids. Table 1 shows the amount of the varying additives that were used in the cost analysis.

3 Results and Discussion

The cost for conditioning the local vegetable oil for SBM purposes is shown in Fig. 2. It was noted that the average cost for conditioning CO, GO, PO, PKO and XB1000 with antioxidant is almost twice the cost of purchasing 0.159 m^3 (159 litre) or a barrel of the CSBF. The initial high cost was later offset when the disposal options were considered as shown in Tables 2 – 4.

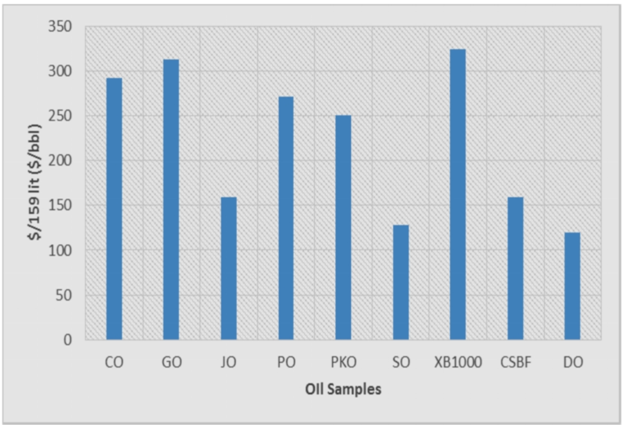

Fig. 2 Cost of Conditioning Local Oils against Commercials Ones

The disposal options were analysed assuming that all drilling operations are carried offshore. Three field waste disposal scenarios were simulated. These were:

(i) Offshore Disposal and Injection;

(ii) Offshore Disposal and onshore landfill treatment disposal;

(iii) Offshore Disposal and onshore thermal treatment disposal.

Table 1 Varying Additives Requirements for 1078 kg/m^3 (9 ppg) Oil Mud Formulations

Parameters	Unit	CO	GO	JO	PO	PKO	SO	XB1000	CSBF	DO
SG		0.919	0.917	0.913	0.913	0.918	0.916	0.872	0.7	0.7
Lime	g	9	8	10	8	8	9	6	5	5
OC	g	3	3	1	1	1	3	6	6	6
Barite	g	55	55	57	57	55	56	73	128	128
CA:PG:ROSE	g	0.35:0.35:0.35								

Table 2 Scenario 1: Cost of Mud Formulations with Both Offshore Disposal and Injection Options

Formulation Cost (A)											
Parameters	**Cost/Unit**		**CO**	**GO**	**JO**	**PO**	**PKO**	**SO**	**XB1000**	**CSBF**	**DO**
Oil		$/ 350 ml	0.4091	0.4545	0.1151	0.3636	0.3182	0.0480	0.4785	0.3500	0.2636
PG	0.4600	$/g	0.1610	0.1610	0.1610	0.1610	0.1610	0.1610	0.1610		
Citric acid	0.0636	$/g	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223	0.0223		
ROSE	0.1458	$/g	0.0510	0.0510	0.0510	0.0510	0.0510	0.0510	0.0510		
Cost per 0.159 m^3 (Cost per 1 Barrel)											
Cost (350 ml)		$/Lab bbl	0.643	0.689	0.349	0.598	0.552	0.282	0.713	0.350	
Cost (159 litre (1 bbl))		$/ bbl	292.284	312.933	158.729	271.635	250.985	128.223	323.801	159.000	
OC	0.0004	$/g	0.0011	0.0011	0.0004	0.0004	0.0004	0.0011	0.0023	0.0011	0.0011
Lime	0.0002	$/g	0.0014	0.0013	0.0016	0.0013	0.0013	0.0014	0.0010	0.0008	0.0008
Barite	0.0003	$/g	0.0154	0.0154	0.0160	0.0160	0.0154	0.0157	0.0148	0.0358	0.0358
Total (Lab-bbl)		$/350 ml	0.6614	0.7067	0.3673	0.6156	0.5695	0.3005	0.7309	0.3878	0.3014
Total (Field-bbl)	Field	$/ bbl	300.45	321.03	166.88	279.64	258.74	136.52	332.02	176.17	136.93
Total Cost/1 000 bbl	**(A)**	$/1 000 bbl	300 455	321 031	166 880	279 640	258 736	136 521	332 020	176 165	136 932
Disposal Options (B)											
Offshore (OFS)			Yes	Yes	Yes	Yes	Yes	Yes	Yes	Partial	Partial (OI)
Onshore (OS)			Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
OFS Disposal Cost	**(B)**	$/Well	450 000	450 000	450 000	450 000	450 000	450 000	450 000	775 000	1 230 000
Total Cost ($/1 000) (A+B)			750 455	771 031	616 880	729 640	708 736	586 521	782 020	951 165	1 366 932
% Savings on DO		$/1 000	45.10	43.59	54.87	46.62	48.15	57.09	42.79	30.42	0.00

*Note: OS = Onshore; OFS = Offshore; OI = Offshore Injection; Lab barrel (bbl) = 350 ml; Field bbl = (Lab bbl * 159/0.35).*

Table 3 Scenario 2: Cost of Mud Formulations with both Offshore and Onshore Landfill Treatment Disposal Options

Formulation Cost (A)											
Parameters	**Cost/Unit**		CO	GO	JO	PO	PKO	SO	XB1000	CSBF	DO
Total (Lab-bbl)		$/350 ml	0.6614	0.7067	0.3673	0.6156	0.5695	0.3005	0.7309	0.3878	0.3014
Total (Field-bbl)	Field	$/ bbl	300.45	321.03	166.88	279.64	258.74	136.52	332.02	176.17	136.93
Total Cost/1 000 bbl	**(A)**	$/1 000 bbl	300 455	321 031	166 880	279 640	258 736	136 521	332 020	176 165	136 932
Disposal Options (B)											
Offshore			Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Onshore			Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
OFS Disposal Cost		$/Well	450 000	450 000	450 000	450 000	450 000	450 000	450 000	-	-
OFS to OS Handling Cost		$ 2 500/day	-	-	-	-	-	-	-	2 500	2 500
Transport to OS	($ 277/tonne)	bbl/tonne	-	-	-	-	-	-	-	8.985	8.985
		1 000 bbl	-	-	-	-	-	-	-	111	111
		$/1 000 bbl	-	-	-	-	-	-	-	37 790	37 790
OS Landfill Treatment		$/Well	-	-	-	-	-	-	-	860 000	860 000
Total Cost	**(B)**	$/ 1 000 bbl	450 000	450 000	450 000	450 000	450 000	450 000	450 000	900 410	900 410
Total Cost (A+B) $/1 000 bbl			750 455	771 031	616 880	729 640	708 736	586 521	782 020	1 076 576	1 037 342
% Savings on CSBF		%	30.29	28.38	42.70	32.23	34.17	45.52	27.36	0.00	3.64

*Note: OS = Onshore; OFS = Offshore; OI = Offshore Injection; Lab barrel (bbl) = 350 ml; Field bbl = (Lab bbl * 159/0.35).*

Table 4 Scenario 3: Cost of Mud Formulations with both Offshore and Onshore Thermal Treatment Disposal Options

Formulation Cost (A)											
Parameters	**Cost/Unit**		**CO**	**GO**	**JO**	**PO**	**PKO**	**SO**	**XB1000**	**CSBF**	**DO**
Total (Lab-bbl)		$/350 ml	0.6614	0.7067	0.3673	0.6156	0.5695	0.3005	0.7309	0.3878	0.3014
Total (Field-bbl)	Field	$/ bbl	300	321	167	280	259	137	332	176	137
Total Cost/1 000 bbl	**(A)**	$/1 000 bbl	300 455	321 031	166 880	279 640	258 736	136 521	332 020	176 165	136 932
Disposal Options (B)											
Offshore			Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No
Onshore			Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
OFS Disposal Cost			450 000	450 000	450 000	450 000	450 000	450 000	450 000	-	-
OFS to OS Handling Cost		$ 2 500/day	-	-	-	-	-	-	-	2 500	2 500
Transport to OS	($ 277/tonne)	bbl/tonne	-	-	-	-	-	-	-	8.985	8.985
		1000 bbls	-	-	-	-	-	-	-	111	111
		$/1000 bbl	-	-	-	-	-	-	-	37 790	37 790
OS Thermal Treatment		$/Well	-	-	-	-	-	-	-	1 400 000	1 400 000
Total Cost	**(B)**	$/ 1000 bbl	450 000	450 000	450 000	450 000	450 000	450 000	450 000	1 440 410	1 440 410
Total Cost (A+B) $/1 000 bbl			750 455	771 031	616 880	729 640	708 736	586 521	782 020	1 616 576	1 577 342
% Savings on CSBF		%	53.58	52.30	61.84	54.87	56.16	63.72	51.62	0.00	2.43

*Note: OS = Onshore; OFS = Offshore; OI = Offshore Injection; Lab barrel (bbl) = 350 ml; Field bbl = (Lab bbl * 159/0.35)*

3.1 Offshore Disposal and Injection Options

It was simulated for all the vegetable oil (Group III) mud samples, to be discharged offshore without much difficulty because of their biodegradability and non-toxicity. For CSBF to be discharged, however, it needs to go through some secondary treatment process as suggested by Derrick, (2001). But for diesel oil (DO), because it is known to be toxic and non-biodegradable, it could only be disposed of offshore by injecting into deep formations as shown in Fig.1. Fig. 3 shows the cost for formulating 0.159 m^3 or one barrel (1 bbl) of oil mud sample. Table 2 shows the cost analysis for the 1st scenario. It was observed that DO recorded the least cost followed by SO; JO; CSBF; PKO; PO; CO; GO; and finally XB1000 in that order. This confirms reports by Vajargah *et al.* (2009) and Growcock and Patel (2011), that the initial cost of formulating synthetic fluids compared to OBM may be doubled or higher.

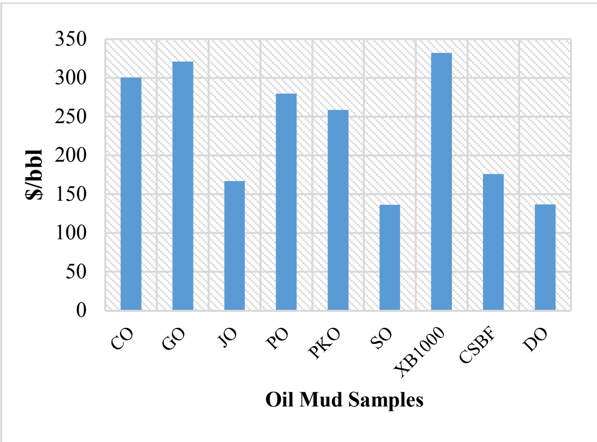

Fig. 3 Cost of Formulating a Barrel of Oil Mud

After considering the first disposal option, it was observed that the cost of formulation and disposal was highest with DO as shown in Fig. 4. This was followed by CSBF; XB1000; GO; CO; PO; PKO; JO and the least was SO. This also confirms the report of Tehrani, (2007) and Vajargah *et al.* (2009) that the cost of containment, hauling, and disposal of OBMs after use are quite high compared to SBMs. This implies that the use of local SBF products with its allowed discharge at drilling sites would offset its initial cost of formulation. The average cost percent of savings compared to the use of DO for all the seven local SBFs was 48.32%. (A is Formulation Cost and B is Disposal Options in Figs. 4-6).

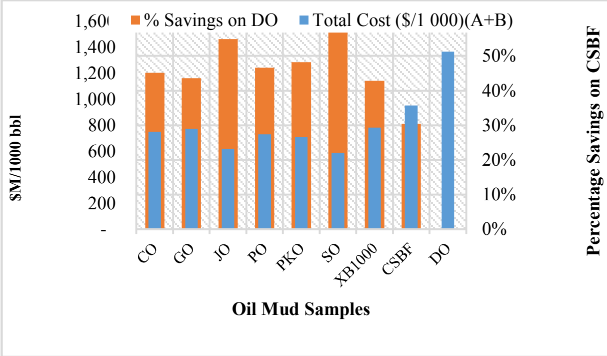

Fig. 4 Cost of Mud Formulations and Offshore Disposal and Injection Option

3.2 Offshore and Onshore Landfill Treatment Disposal Options

For this scenario, it was simulated for all the vegetable oil (Group III) mud samples to be discharged offshore just as in scenario one because of their biodegradability and non-toxicity. For CSBF and DO, it was assumed that the contaminated fluid would not be allowed to be discharged offshore (no secondary treatment is allowed) therefore the cuttings must be transported onshore for further treatment and landfill disposed as shown in Table 3 and Fig. 5. After considering this second disposal option, it was observed that the cost of formulation, containment handling, hauling, and disposal onshore was highest with CSBF, followed by DO. The cost of CSBF was more than DO because they were exposed to the same treatment onshore but the cost of formulating its mud was higher than that of DO. The others followed in this order XB1000; GO; CO; PO; PKO; JO and the least was SO. This also confirms the report by Tehrani (2007) and Vajargah *et al.* (2009) that the cost involved after using OBMs use are quite high compared to SBMs. That is the use of local SBFs products with its allowed discharge at drilling sites would offset its initial cost of formulation. The average cost percent of savings compared to the use of CSBF for all the seven local SBFs was about 34.38.

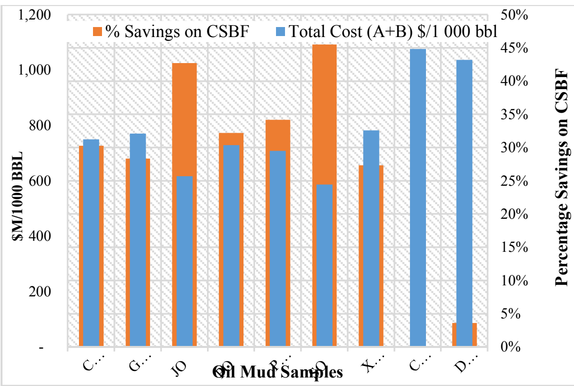

Fig. 5 Cost of Mud Formulations and Offshore and Onshore Landfill Treatment Disposal Options

3.3 Offshore and Onshore Thermal Treatment Disposal Options

For this scenario, it was simulated for all the vegetable oil (Group III) mud samples, to be discharged offshore just as in scenarios 1 and 2 because of their biodegradability and non-toxicity. For CSBF it was assumed that the contaminated fluid would not be allowed to be discharged offshore (no secondary treatment is allowed just as in scenario 2) therefore the cuttings must be transported onshore for further treatment. Landfill treatment disposal option was simulated to be prohibited but thermal treatment is acceptable. This option was also applicable to DO as indicated in Table 4 and Fig. 6. After considering this third disposal option, it was observed that the cost of formulation, containment handling, hauling, and disposal onshore was highest among the options. The cost of disposal was highest with CSBF, followed by DO with the same reason just as in scenario 2. The others followed in this order XB1000; GO; CO; PO; PKO; JO, and the least was SO. This also confirms the use of local SBFs products with its discharge at drilling sites would offsets its initial cost of formulations. The average cost percent of savings compared to the use of CSBF for all the seven local SBFs was about 56.30.

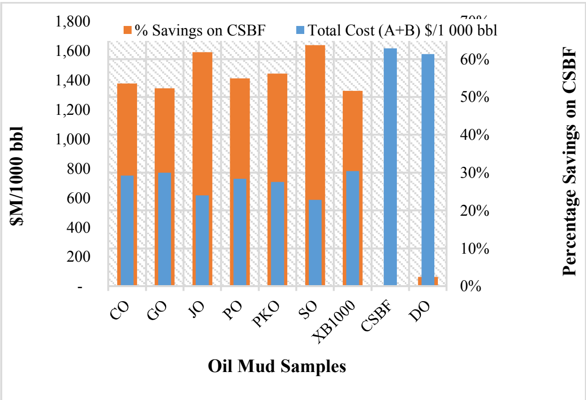

Fig. 6 Cost of Mud Formulations and Offshore and Onshore Thermal Treatment Disposal Options

3.4 Local SBFs Sustainability

According to Drexhage and Murphy, (2010), sustainability is the "*development which meets the needs of the present without compromising the ability of future generations to meet their own needs*". The three pillars of sustainability are economic development, social equity and environmental protection. The sustainability of these local SBFs in Ghana are very high as out of the total surface area of 238 540 km^2 available, 230 020 km^2 are suitable for land use (agriculture) purposes (Togobo and Addo, 2007). Some available plant suitable for bio-fuel production in Ghana includes oil palm, coconut, groundnut, shea-nut, jatropha, cashew, cotton, rubber, sugarcane, cassava among others. The cultivation of these crops have seen tremendous growth over the years. In 2000, total production of groundnut was 209 000 tonnes but increased to 530 887 tonnes in 2010 (Angelucci and Bazzucchi 2013). According to the 2012 report of the Ministry of Food and Agriculture, Ghana, 164 700 tonnes of soybeans was produced. As at 2013, the United States Department of Agriculture statistics showed that about 305 000 tonnes of coconut nuts were also produced in Ghana covering 60 000 hectare. Ghana currently has a total of 305 758 hectares of oil palm plantation (Anon, 2013). It is estimated that 243 852 tonnes of palm oil is produced annually (Anon, 2013). Five out of the ten regions in Ghana are suitable for oil palm cultivation (Anon, 2013). A total of 769 000 hectares have been acquired by various companies for the cultivation of jatropha (Anon, 2010). More than 37 % of Ghana's cropland is estimated to have been acquired for jatropha plantations (Anon, 2010). The co-product of the oil pressing process is pressed cake which is a good organic soil improver (organic fertilizers rich in Nitrogen, Phosphorus and Potassium (NPK)) (Amoah, 2006 and Anon, 2010). More lands are been cultivated for the production of these local pseudo-oils (vegetable esters). The use of these local SBFs are therefore very sustainable.

4 Conclusions and Recommendation

4.1 Conclusions

The following conclusions are drawn from the studies conducted:

(i) The cost for formulating 0.159 m^3 (1 barrel) of mud was least for DO followed by SO; JO; CSBF; PKO; PO; CO; GO; and finally XB1000 in that order. Thus the initial cost of formulating synthetic fluids compared to OBM may be doubled or higher.

(ii) Considering all offshore disposal options, it was observed that the cost of formulation and disposal was highest with DO followed by CSBF; XB1000; GO; CO; PO; PKO; JO and the least was SO. Thus the cost of containment, hauling, and disposal of OBMs after use are quite high compared to SBMs. That is, the use of local SBFs products with its allowed discharge at drilling sites would offset its initial cost of formulations.

(iii) The cost percent of savings compared to the use of DO for all the seven local SBFs were higher than that of the CSBF.

(iv) For CSBF and DO to be disposed of onshore through landfill treatment or thermal treatment disposal options, the cost of formulation, containment handling, hauling, and disposal onshore was highest for CSBF followed by DO, then XB1000; GO; CO; PO; PKO; JO and the least was SO.

(v) The average cost percent of savings of the local use of vegetable oils over the use of DO or CSBF were 48.32%; 34.38% and 56.30% respectively.

(vi) Most of the local pseudo oils samples have exhibited better cost benefits over DO and CSBF, and therefore may serve as potential replacements for the commercial oil base fluids.

4.2 Recommendation

It is recommended that the oil and gas industry should consider the use of these cheaper local ester oils in their mud formulations to reduce overall drilling operational cost.

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