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Treatment of the Bitumen and Heavy Oil in Zubair Formation/ East Baghdad Field

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Abstract

Bitumen precipitation refers to the separation and settling of heavier, denser hydrocarbon compounds from crude oil, which can occur under certain conditions of pressure and temperature. Crude oils with high viscosity, high density, low API gravity, and high sulfur content are more prone to bitumen precipitation. Understanding these properties is essential in the oil industry for predicting the behavior of crude oils during production, transportation, refining, and storage. The viscosity, density, API, and sulfur content of crude oil were examined as part of this investigation. The viscosity test is achieved by using automated viscometer apparatus with ASTM D 7042 standard, while the sulfur content test is performed by using Sindie 2622 Sulfur Analyzer with ASTM D 7039 standard. However, density and API gravity tests are done depending on manually condition related to mixing, time, method, temperature and percentages until obtained an optimized result. In order to determine the reduction in viscosity and other physical properties of crude oil, which will offer a better solution against the precipitating of asphaltene and Bitumen that essentially lead to plug the production pipe and stop oil production. The chosen solvent was kerosene, which mixed with three samples of crude oil over the course of three periods under standard conditions from the Zubair formation/East Baghdad field [EB-58]. However, the kerosene is selected because it has a high specific gravity which is considered as the best solvent for heavy crude oil and it is inexpensive. Moreover, in experimental work used three percentage of kerosene to mix with crude oil; [6%, 12% and 18%]. The results show that all ratio of kerosene addition will optimize the crude oil properties. The best result was gotten by adding 18 % kerosene to crude oil and the best optimization results were viscosity 89.3%, density 4.27%, API 39.5% and sulfur content 21.2%. In addition to reduce the viscosity of the heavy crude oil, using kerosene for 1 job will minimize the expenses approximately 1,177,000 IQD.

Keywords: Heavy Crude Oil, Oil Density, Oil Viscosity, API, Sulfur Content.

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معالجة البتيومين و النفط الثقيل في مكمن الزبير/ حقل شرقي بغداد

الخلاصة:

يشير ترسيب البيتومين إلى عملية فصل وتسرب المركبات الهيدروكربونية الأثقل والأكثر كثافة من النفط الخام، والتي يمكن أن تحدث في ظل ظروف معينة من الضغط ودرجة الحرارة. النفوط الخام ذات اللزوجة العالية، والكثافة العالية، و API المنخفض، والمحتوى الكبريتي المرتفع هي أكثر عرضة لتكون الاسفلتينات والبيتومين. يعد فهم هذه الخصائص أمرًا ضروريًا في صناعة النفط للتنبؤ بسلوك النفط الخام أثناء الإنتاج والنقل والتكرير والتخزين. تم إجراء اختبار اللزوجة باستخدام جهاز قياس اللزوجة الآلي بمعيار ASTM D 7042، في حين يتم إجراء اختبار محتوى الكبريت باستخدام محلل الكبريت Sindie 2622 بمعيار ASTM D 7039. ومع ذلك، يتم إجراء اختبارات الكثافة والجاذبية API اعتمادًا على الطرق العملية والمتعلقة بالخلط والوقت والطريقة ودرجة الحرارة والنسب المئوية حتى يتم الحصول على نتائج مثالية. تم فحص اللزوجة والكثافة ، API، ومحتوى الكبريت لنموذج نفط خام من أجل تحديد كمية الانخفاض في اللزوجة والخصائص الفيزيائية الأخرى للنفط الخام، والذي سيوفر حلاً أفضل ضد ترسب الأسفلتين والبيتومين الذي يؤدي بشكل أساسي إلى سد أنبوب الإنتاج وإيقاف إنتاج النفط. تم اختيار الكيروسين الغير المهدرج كمذيب فعال، والذي تم خلطه مع ثلاث عينات من النفط الخام على مدار ثلاث فترات تحت ظروف قياسية من تكوين الزبير/ حقل شرق بغداد(EB-58) . تم اختيار الكيروسين لأنه يحتوي على ورن نوعي عالي والذي يعتبر أفضل مذيب للزيت الخام الثقيل وغير مكلف. علاوة على ذلك، خلال العمل المختبري، تم استخدام ثلاث نسب مئوية من الكيروسين لمزجها بالزيت الخام. (6٪ و 12٪ و 18٪). أظهرت النتائج أن كل نسبة إضافة من الكيروسين قد حسنت من خصائص النفط الخام. حيث تم الحصول على أفضل نتيجة بإضافة 18٪ كيروسين إلى الزيت الخام وأفضل نتائج التحسين كانت اللزوجة 89.3٪، الكثافة 4.27٪، API 39.5٪ ومحتوى الكبريت 21.2٪. ان استخدام الكيروسين الغير مهدرج وحقنه داخل البئر للعملية الواحدة، سيقلل من النفقات تقريبًا 1,177,000 دينار عراقي.

1. <u>Introduction:</u>

1.1. Preface

Crude oil that has an API gravity lower than 20° is sometimes categorized as heavy or extremely dense hydrocarbon fluid. In the context of ambient environments, it is seen to exhibit the characteristics of a liquid, namely possessing a dense non-aqueous phase [1]. This inquiry examined four physical attributes. Heavy crude oils may be characterized as a cohesive collection of molecules with varying molecular weights between 1500 and 2000, mostly consisting of aromatic and aliphatic components [2]. In general, the substances under consideration exhibit a notably high level of viscosity, which spans a spectrum extending from the consistency of dense molasses to a solid state when subjected to ambient conditions. In addition to various metallic elements, particularly nickel and vanadium, these substances also include substantial quantities of asphaltene, resins, nitrogen, and heteroaromatic compounds including Sulphur. Unconventional crude oils, often referred to as heavy crude oils, are characterized by their inability to undergo standard techniques of production, transportation, and refining [3]. The physicochemical characteristics of heavy crude oil provide significant challenges in both the production and processing stages of heavy oil operations.

Open Access
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In addition to their physical properties, heavy crudes have distinctive molecular interactions, namely van der Waals interactions. While these interactions are rather insignificant for small molecules, they become more pronounced when considering asphaltenes. It is noteworthy that, under low temperature conditions, these proximate interactions occur with greater frequency and thus lead to heightened viscosity of the oil. Additional chemical interactions that contribute to the augmentation of viscosity occur at free radical sites, which are linked to condensed polycyclic aromatic complexes with very reactive unpaired electrons.

Pipeline transmission of heavy crude oils is not possible unless the oil is first processed to lower its viscosity. Blending the oil with lighter hydrocarbons is a standard method of doing this. The viscosity of the resultant mixture is determined by the relative densities and viscosities of the oil and solvent, as well as the degree of dilution. The radius of gyration of asphaltene aggregates also drops, as measured by small-angle X-ray scattering (SAXS). Similar results are seen when combining hydrocarbons and solvents with polar functional groups in their molecules to dilute heavy crude oils. Hansen's hypothesis screens solvent efficiency. Hydrocarbons are less viscous than solvents with significant hydrogen bonding. When stated in absolute viscosity, their interactions with asphaltenes are concealed. Only polar solvents with minimal hydrogen bonds reduce diluted crude oil viscosity [4]. The problem statement is summarized as shut down many wells that is produced from Zubair formation at EB-81, EB-58 Eb-82, EB-92, EB-21 and Eb-11 wells as a result of asphaltene precipitation and low flow rate of heavy crude oil. The objective of this research is to optimize the physical properties of crude oil by injecting a selected solvent into the borehole while lowering the viscosity, density sulfur content as well as increase the API of crude oil. Increasing oil consumption is creating extremely substantial global resources of heavy oils that are comparable to conventional oils. The viscosity reduction of heavy crude oil with an appropriate cost is considered the main objective of current study.

1.2. Asphaltenes

The asphaltene fraction exhibits a significantly low hydrogen-to-carbon ratio and is composed of densely condensed ring compounds. Solution techniques have determined that the prevailing molecular weights of these compounds fall within the range of 5000 to 10,000 (although mass spectrometer techniques estimate molecular weights approximately one order of magnitude lower) [5].

1.2.1. Chemical Structure of Asphaltenes; The first perspective posits that asphaltene consists

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of a solitary, extensive polycyclic aromatic nucleus, accompanied by aliphatic chains connected to its outside edges Figure (1). The alternative perspective posits that asphaltene consists of several smaller polycyclic cores interconnected by aliphatic bridges, such as sulphides and esters Figure (2). The second perspective is widely embraced by researchers because to its ability to explain a majority of the reported physical and chemical characteristics of the asphaltene molecule [6, 7].

1.2.2. Physical and Chemical Properties contain viscosity, density, API, and sulphur. The physical and physico-chemical characteristics of asphaltenes vary from neutral resins. The molecular weight of asphaltenes is high. Asphaltene's molecular weight fluctuates greatly depending on measuring technique and circumstances. Asphaltene is dark or black powdered substance made by treating petroleum, petroleum waste, or bituminous materials with a low-boiling liquid hydrocarbon [8]. According to Nazmul et al., asphaltene has these physical properties:

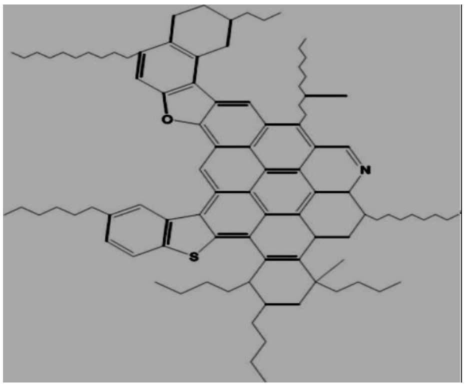

Fig. (1): Single condensed polycyclic aromatic core.

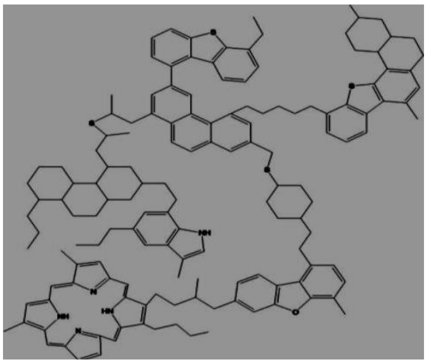

Fig. (2): Multiple Smaller Polycyclic aromatic cores with aliphatic bridges.

Aggregate size is 20-200 µm. The porosity of aggregates increases with size. Permeability quickly rises with aggregate size. Settling velocity is 100-600 µm/s. Due to asphaltene's complexity, its chemical characteristics rely exclusively on the crude.

1.2.3. Breakdown of Asphaltenes and Viscosity Reduction is described. With heavier crude oil sources entering the market, now is a good moment to explore new research possibilities. At 100°F, certain crude oils may reach 15,000 centistokes. The viscosity must be below 150 centistokes at 100°F for pipeline transmission of these crude oils. For instance, crude oils are

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Vol. 14, No. 2, June 2024, pp. 45-57

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E- ISSN: 2710-1096

combined with kerosene distillate. This procedure consumes a lot of commercial product since up to 30% kerosene must be added to lower viscosity [9].

1.3. Area of study

The area of study at East Baghdad field (EB) include the wells that the target of drilling reach to Zubair Formation such as EB-81, EB-58 Eb-82, EB-92, EB-21 and Eb-11. In this research the sample is obtained from EB-58, as shown in Figure (3) [10].

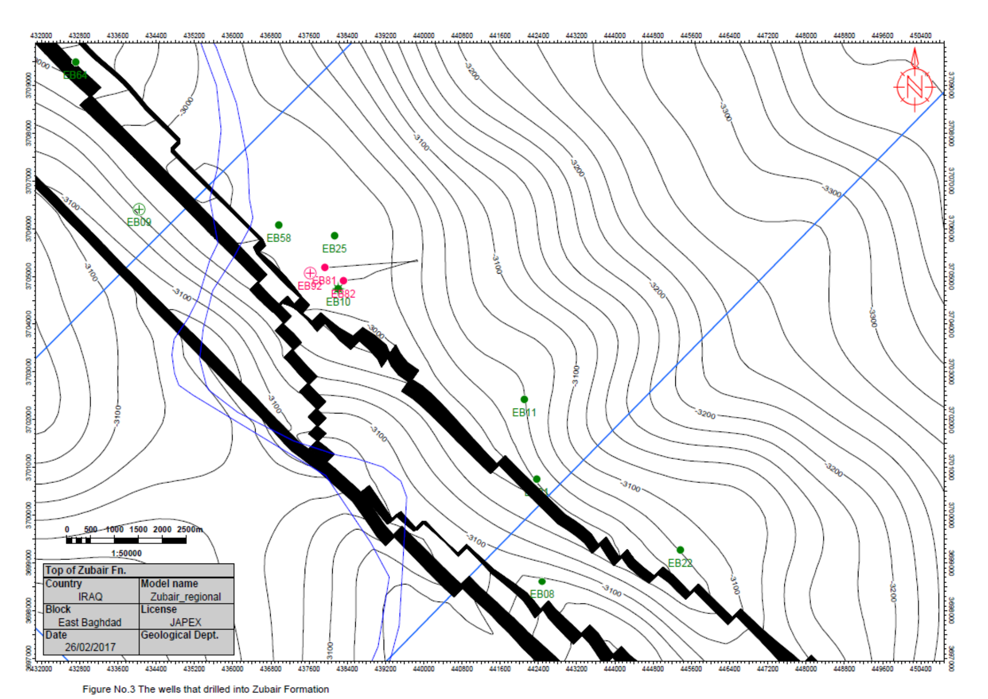

Fig. (3): The wells that drilled into Zubair Formation

2. <u>Aim of Study and Reason of Kerosene Selection</u>

2.1. Aim of Study

The primary objective of this research is to gain insight into the function of asphaltenes in high viscosity oils. Additionally, the study aims to assess the effectiveness of viscosity reduction by blending with certain solvents at varying ratios. The crucial inquiry pertains to the management of high-viscosity crude oil and its challenging characteristics throughout the various stages of production through the wellbore, necessitating the enhancement of crude oil features. This study focuses on the reduction of viscosity in heavy crude oil by the use of kerosene at varying ratios. The primary objective is to investigate the impact of various solvent ratios on the breakdown of

Open Access
Vol. 14, No. 2, June 2024, pp. 45-57

P- ISSN: 2220-5381
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asphaltenes, as well as to analyzed the solvent's efficacy in dispersing the asphaltenes and preventing the formation of their aggregates.

2.2. Reason of Kerosene Selection:

In this research, the solvent that was selected is Kerosene from other petroleum products because the kerosene is considered as:

1- A good dilution.

2- Low cost.

3- The demand on kerosene is lower than Gasoil.

4- Don't create slugs (agglomeration) as it creates when using the light dilutions heavy naphtha and toluene while they are mixing with crude oil. However, when use the light solvent may some problem take place such as it will spear the crude oil in two layers, one as light and second as heavy (sludge) that will causes a agglomeration and close the production pipe line.

3. Experimental Work

3.1. Materials

3.1.1. Heavy crude oil

Heavy crude oil was supplied from East Baghdad oil fields (EB)/ Zubair Formation which have been taken in three different periods (three samples of Crude oil), the API of heavy crude oil is shown in Table (1).

Table (1): Physical API of East Baghdad Crude Oil

No.	Samples Date	API
1	Sample, 5/9/2017	14.60
2	Sample, 9/11/2017	16.00
3	Sample, 30/8/2017	16.70

3.1.2. Solvent:

Kerosene: was supplied from Atmospheric Distillation Unit / Al-Duraa Refinery with physical properties as; 1) Flash point=40 minimum, 2) Smoke point=25 mm max, 3) End point= 225 C^o, 4) Initial point= 160 C^o, 5) Sulfur = 0.3%=3000 ppm, 6) Freezing point= -51 C^o.

Open Access
Vol. 14, No. 2, June 2024, pp. 45-57

P- ISSN: 2220-5381
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3.2. Tests

The physical properties which are selected in order to study the effect of adding kerosene as solvent to the crude oil are Density, Viscosity, Sulfur content and API. All figures below are depending on lab result at Tables (2) and (3).

3.2.1. Density

The density of crude oil was clearly decreased with increasing solvent concentration as shown in Figure (4). In sample 1, the density is decreased slowly with increasing solvent concentration from (0% to 6%) while the density is decreased sharply with increasing solvent concentration from (6% to 12%) and the reduction of density will be decreased very slowly at increasing solvent concentration from (12% to 18%). In sample 2, the density is decreased sharply with increasing solvent concentration from (6% to 12%) and the reduction of density will be decrease very slowly at increasing solvent concentration from (12% to 18%). In sample 3, density of crude oil was decreased slowly with increasing solvent concentration from (6% to 12%) while it is decreasing sharply at increasing solvent concentration from (12% to 18%).

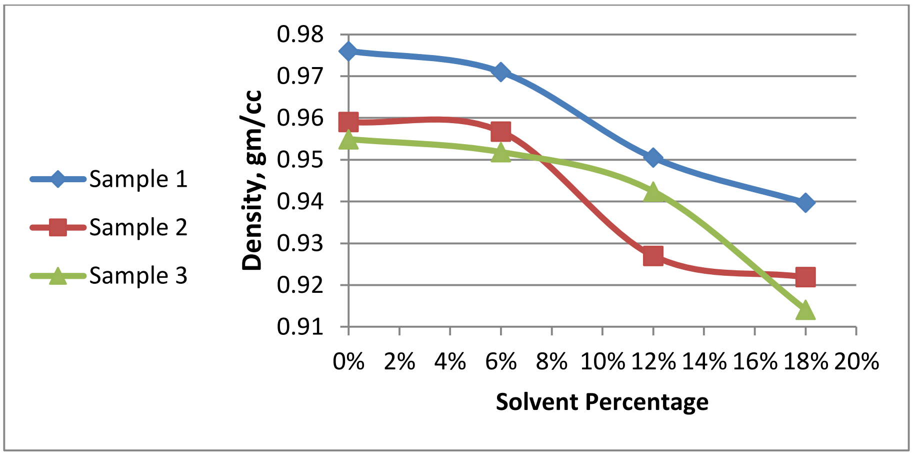

Fig. (4): Density of crude oil decreased with adding Kerosene at different Concentrations.

The result shows the maximum percentage of density reduction recorded while adding the Kerosene as a solvent was 3.719262, 3.868613 and 4.272699 for Sample 1, sample 2, and sample 3 respectively.

3.2.2. Viscosity

The viscosity test is achieved by using automated viscometer apparatus with ASTM D 7042 standard, as shown in Figure (5).

Open Access
Vol. 14, No. 2, June 2024, pp. 45-57

P- ISSN: 2220-5381
E- ISSN: 2710-1096

Fig. (5): Automated Viscometer Apparatus

The viscosity was clearly decreased with increasing solvent concentration as shown in Figure (6). In sample 1, the viscosity of crude oil was decreased slowly with increasing solvent concentration from (0% to 6%) while the decrease in viscosity of crude oil was gradually increased with increasing solvent concentration from (6% to 12%) and finally, the viscosity of crude oil will return to decrease slowly with increasing solvent concentration from (12% to 18%). In sample 3, the viscosity is gradually decreased slowly with increasing solvent concentration from (0% to 18%). In sample 2, the viscosity of Crude oil was decreased slowly with increasing solvent concentration from (0% to 6%) while the viscosity of crude oil was decreased sharply with increasing solvent concentration from (6% to 12%) and finally, the viscosity of crude oil will return to decrease slowly with increasing solvent concentration from (12% to 18%). In sample 3, the viscosity is gradually decreased slowly with increasing solvent concentration from (0% to 18%). In typical scenarios, the viscosity of heavy crude oils may be decreased by diluting them with light petroleum fractions at a concentration of at least 25%. It is important to note that this dilution does not alter the inherent properties of the heavy crude oils, and the reduction in viscosity is solely attributed to the dilution process. The utilisation of a polar solvent with a concentration not surpassing 12% has been identified as a novel approach that leads to a significant decrease in viscosity. This reduction can be attributed to the breakdown of asphaltenes and their dispersion, which effectively prevents the agglomeration of asphaltene aggregates. It is worth noting that this action remains dominant even during solvent recovery.

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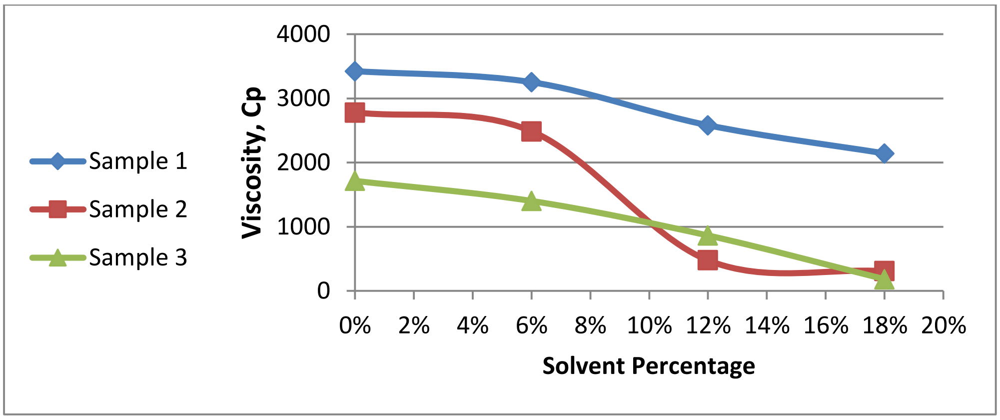

Fig. (6): Viscosity of crude oil decreased with adding Kerosene at different Concentrations.

The results show superior effect of adding solvent to crude oil; the maximum percentage of viscosity reduction recorded while adding the Kerosene as solvent was 37.46059, 88.85254 and 89.2982 for Samples 1, 2 and 3 respectively.

3.2.3. Sulfur content

The sulfur content test is performed by using Sindie 2622 sulfur analyzer apparatus with ASTM D 7039 standard, as shown in Figure (7). Sulfur content is decreased with increasing concentration of solvent as shown in Figure (8). In samples 1.2 and 3, the reduction in sulfur content is gradually increased slowly with increasing solvent concentration from (0% to 18%). Moreover, in sample 2 the addition of solvent in percentage between (12%-18%) into crude oil will be approximately constant.

Fig. (7): Sindie 2622 Sulfur Analyzer Apparatus

Journal of Petroleum Research and Studies

Open Access
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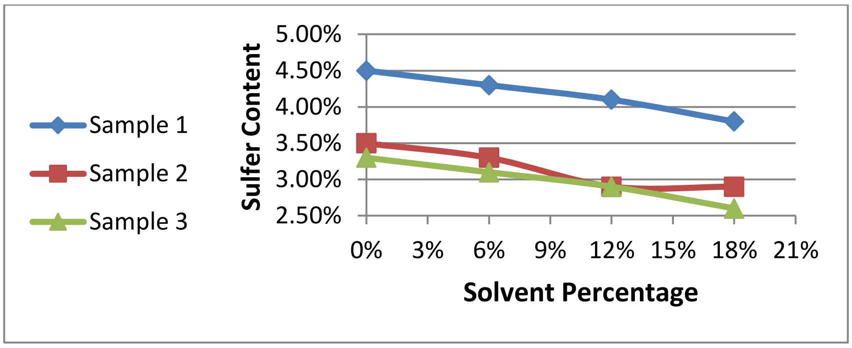

Fig. (8): Sulfur content in crude oil decreased with adding Kerosene at different Concentrations

The maximum increasing in Sulfur content value while adding the Kerosene as solvent for the three samples 1, 2 and 3 are 21.21%, 17.14% and 15.55% respectively at solvent percentage 6 %.

3.2.4. API Value

As can be seen in Figure (7), the API grew as the concentration of the solvent did. The breakdown of asphaltenes may be seen in the rising API value, which is both an indicator and proof of this process. In sample 1, the API content grows mildly when the solvent concentration is raised from 0% to 18%. When increasing the solvent concentration from 0% to 6% in sample 2, the API of crude oil rose gradually; when increasing the solvent concentration from 6% to 12%, the API of crude oil rose steeply; and when increasing the solvent concentration from 12% to 18%, the API of crude oil rose once again gradually. Sample 3 shows a modest, steady rise in API content when solvent concentration is changed from 0% to 18%.

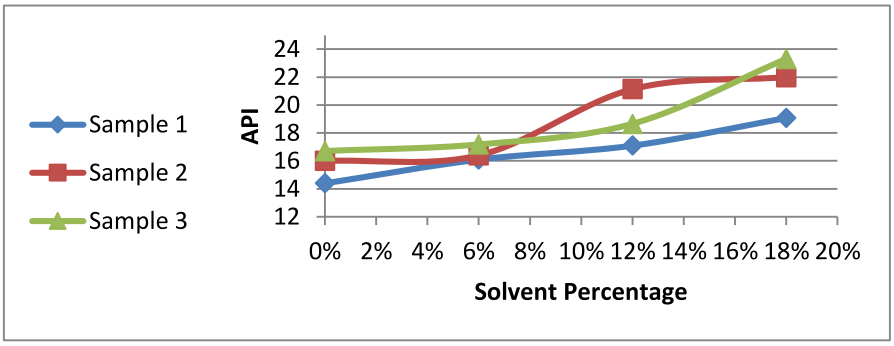

Fig. (7): API of crude oil changed with adding Kerosene at different Concentrations

The three samples, labelled as 1, 2, and 3, had greatest increases in API value when kerosene was used as a solvent. The increases were measured at 32.5%, 37.5%, and 39.5% for samples 1, 2, and 3, respectively. These increases occurred at a solvent fraction of 18%.

Open Access
Vol. 14, No. 2, June 2024, pp. 45-57

P- ISSN: 2220-5381
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Table (2): Results of Adding 3 Concentrations of Kerosene to the Crude Oil

No.	Samples Date	Percentage of adding Kerosene	Results				
			Test Name				
			Viscosity @ 40 C°		Density (gm/cc)	API	Sulfur Content
			C.stock	C.poise			
1	Sample, 5/9/2017	0%	3509.5	3425.2	0.976	14.4	4.50%
		6%	3388.3	3252.8	0.971	16.1	4.30%
		12%	2715	2580.8	0.9505	17.1	4.10%
		18%	2279.6	2142.1	0.9397	19.08	3.80%
2	Sample, 9/11/2017	0%	2900.8	2781.8	0.959	16	3.50%
		6%	2600.5	2487.9	0.9567	16.4	3.30%
		12%	516.83	479.1	0.927	21.14	2.90%
		18%	366.35	310.1	0.9219	22	2.90%
3	Sample, 30/8/2017	0%	1796.7	1715.6	0.9549	16.7	3.30%
		6%	1473.9	1402.9	0.9518	17.17	3.10%
		12%	917.16	864.3	0.9424	18.65	2.90%
		18%	200.89	183.6	0.9141	23.3	2.60%

Table (3): The Enhancement in Crude Oil Properties Values by Addition of Different Kerosene Ratios.

Samples NO.	Solvent percentage %	Viscosity %	Density %	API %	Sulfur cont. %
1	18%	37.460	3.71	32.5	**15.55**
	12%	24.65	2.61	18.75	**8.88**
	6%	5.03	0.51	11.80	**4.44**
2	18%	88.85	3.86	37.5	**17.14**
	12%	82.77	3.33	32.125	**17.14**
	6%	10.56	0.24	2.5	**5.714**
3	18%	89.29	4.27	39.52	**21.21**
	12%	49.62	1.31	11.67	**12.12**
	6%	18.22	0.32	2.81	**6.06**

4. Brief Economic Study

The price of 1 L of Kerosene is 300 ID.

The price of 1 L of gasoil is 400 ID.

Note: 1 bbl = 159 L.

1 M^3 = 1000 L. Then:

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Vol. 14, No. 2, June 2024, pp. 45-57

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- The price of 1 bbl of gas oil = 159 L * 400 ID= 63600 ID/1bbl.
- The price of 1 bbl of kerosene = 159 L * 300 ID= 47700 ID/1bbl.

Moreover, by depending on the report of gas oil injection for EB-92 [11] into Zubair formation, the injection of gasoil volumes and its economic comparison with injecting Kerosene as shown in Table (4).

Table (4): The Economical Comparison between Gasoil and Kerosene as a Solvent

No	Gas oil volumes injection	Equivalent price of gas oil	Kerosene volumes injection	Equivalent price of kerosene	Outcome Results
1	30 bbl @ 15/6/2016	=30 bbl * 159 (L/bbl) * 400 (ID/L)=1,908,000 ID.	30 bbl	=30 bbl * 159 (L/bbl) * 300 (ID/L)=1,431,000 ID.	477,000 ID
2	7 M^3 16/6/2016	=7 M^3 * 1000 (L/M^3) * 400 (ID/L)= 2,800,000	7 M^3	=7 M^3 * 1000 (L/M^3) * 300 (ID/L)= 2,100,000	700,000 ID
3	Sum	By using kerosene for 1 job will minimize the expenses into:			**1,177,000**

5. Conclusions

1- The results show that workover operations by injection of kerosene into the stopped flowing wells which is closed by slugs of asphaltene and bitumen in order to open the well for production are very suitable, perfect reduction in density, API and viscosity and minimize the expenses for these jobs.

2- By using kerosene for 1 job will minimize the cost at lease to approximately 1,177,000 ID.

3- The best result is gotten at addition of 18 % kerosene to crude oil and the best results are viscosity 89.3%, density 4.27%, API 39.5% and sulfur content 21.2%.

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Open Access
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