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## Evaluation of natural and chemical demulsification agents for preventing crude oil emulsification in different crude oil Types

Ibrahim Al-dukali<sup>1</sup>, Hamad Abu Azoum<sup>1</sup>, Ziyad. Ben Abdulhafid<sup>2</sup>,  
Masouda farhat, Mohaned Sassi<sup>3</sup>, Salah aldin Youssef<sup>3</sup>  
Fatmah abdul salam<sup>4</sup>

<sup>1,3</sup>Petroleum and gas Engineering Department, Faculty of engineering,  
Sheba University, Libya

<sup>2</sup>. Petroleum Engineering Department, College of Applied Sciences'  
Technology, Al-Awata, Libya

<sup>4</sup> Faculty of sciences, Sabah University - Libya  
[ibr.aldukali@sebhou.edu.ly](mailto:ibr.aldukali@sebhou.edu.ly)

### Abstract

Emulsification is one of the most persistent operational challenges in the petroleum industry, adversely affecting crude oil production, transportation, and processing. A thorough understanding of emulsion formation and stability is essential for developing efficient demulsification strategies that minimize corrosion, viscosity increase, and flow assurance problems. This study investigates the formation of water-in-oil emulsions in crude oil flow lines and evaluates the performance of different demulsification agents, including organic solvents, commercial demulsifiers, polymers, and a natural material (MLX), as environmentally friendly alternatives. Centrifuge experiments were conducted using two crude oil types (M.F. and S.F.) with different API gravities. All tests were performed at 1500 rpm, 60 °C, and a centrifugation time of 10 minutes, using additive concentrations ranging from 0.25% to 1%. Separation efficiency was evaluated based on the volume of separated water and the reduction in emulsion layer thickness. The results indicate that commercial demulsifiers achieved the highest separation efficiency, particularly for the lighter crude oil (M.F.). Organic solvents such as xylene and hexane showed moderate effectiveness, with performance strongly dependent on crude oil

properties. Polymer-based treatments exhibited limited efficiency, especially for the heavier crude oil (S.F.). Notably, the natural material MLX demonstrated a clear concentration-dependent improvement in demulsification performance. Increasing the MLX concentration to 0.5% and 1% significantly enhanced water separation and reduced the emulsion layer in both crude oil samples. These findings confirm the potential of MLX as a promising natural and sustainable demulsification agent and highlight its applicability as an effective alternative or supplement to conventional chemical demulsifiers in crude oil processing.

**Keywords:** crude oil emulsion, demulsification, natural demulsifier, centrifugal separation, green chemicals.

## تقييم عوامل إزالة الاستحلاب الطبيعية والكيميائية لمنع استحلاب النفط الخام في أنواع مختلفة من النفط الخام

إبراهيم الدوكالي<sup>1</sup>، حمد أبو عزوم<sup>1</sup>، زياد بن عبد الحفيظ<sup>2</sup>، مسعودة فرحات،  
مهند ساسي<sup>3</sup>، صلاح الدين يوسف<sup>3</sup>، فاطمة عبد السلام

<sup>1,3</sup> قسم هندسة النفط والغاز - كلية الهندسة - جامعة سبها، ليبيا

<sup>2</sup> قسم هندسة النفط - كلية العلوم التطبيقية والتكنولوجية - العواتة، ليبيا

<sup>4</sup> كلية العلوم - جامعة سبها - ليبيا

[ibr.aldukali@sebhau.edu.ly](mailto:ibr.aldukali@sebhau.edu.ly)

### الملخص

يُعدّ الاستحلاب أحد أكثر التحديات التشغيلية استمراريةً في صناعة النفط، إذ يؤثر سلبيًا على إنتاج النفط الخام ونقله ومعالجته. ويُعدّ الفهم الشامل لتكوين المستحلبات واستقرارها ضروريًا لتطوير استراتيجيات فعّالة لفصل المستحلبات، مما يقلل من التآكل وزيادة اللزوجة ومشاكل ضمان التدفق. تبحث هذه الدراسة في تكوين مستحلبات الماء في الزيت في خطوط تدفق النفط الخام، وتقيم أداء عوامل فصل المستحلبات المختلفة، بما في ذلك المذيبات العضوية، وعوامل فصل المستحلبات التجارية، والبوليمرات، ومادة طبيعية (MLX)، كبديل صديقة للبيئة. أُجريت تجارب الطرد المركزي باستخدام نوعين من النفط الخام (M.F. و S.F.) بدرجات API مختلفة. أُجريت جميع الاختبارات عند 1500 دورة

في الدقيقة، و60 درجة مئوية، وزمن طرد مركزي 10 دقائق، باستخدام تراكيز إضافات تتراوح من 0.25% إلى 1%. تم تقييم كفاءة الفصل بناءً على حجم الماء المفصول وانخفاض سُمك طبقة المستحلب. تشير النتائج إلى أن المواد التجارية المزيلة للاستحلاب حققت أعلى كفاءة فصل، لا سيما للنفط الخام الخفيف (M.F.). أظهرت المذيبات العضوية، مثل الزيولين والهكسان، فعالية متوسطة، حيث يعتمد الأداء بشكل كبير على خصائص النفط الخام. أما المعالجات القائمة على البوليمرات، فقد أظهرت كفاءة محدودة، خاصة للنفط الخام الثقيل (S.F.). والجدير بالذكر أن المادة الطبيعية MLX أظهرت تحسناً واضحاً في أداء إزالة الاستحلاب، يعتمد على التركيز. فقد أدى رفع تركيز MLX إلى 0.5% و 1% إلى تحسين فصل الماء بشكل ملحوظ وتقليل طبقة المستحلب في كلتا عينتي النفط الخام. تؤكد هذه النتائج إمكانات MLX كعامل طبيعي ومستدام واعد لإزالة الاستحلاب، وتُبرز إمكانية استخدامه كبديل فعال أو مكمل للمواد الكيميائية التقليدية المزيلة للاستحلاب في معالجة النفط الخام.

**الكلمات المفتاحية:** مستحلب النفط الخام، إزالة الاستحلاب، مزيل استحلاب طبيعي، الفصل بالطرد المركزي، المواد الكيميائية الخضراء.

## 1- Introduction

Crude oil is rarely produced as a single phase, as it is commonly accompanied by formation water. The presence of water introduces several operational and economic challenges, including increased production, transportation, and processing costs. Emulsions may form at almost all stages of oil production, including within reservoirs, wellbores, surface facilities, and transportation pipelines. Produced oilfield emulsions are generally classified into water-in-oil (W/O), oil-in-water (O/W), Figure (1), (2), and complex or multiple emulsions. Among these, water-in-oil emulsions are the most prevalent in petroleum operations. The separation of water from crude oil has been a fundamental challenge since the early development of the petroleum industry. Although gravity settling was initially employed, it was later recognized that a significant portion of recoverable oil remained trapped within stable emulsions. Turbulence, shear forces, and the presence of natural surface-active components such as asphaltenes and resins promote emulsion

formation. These components form rigid interfacial films around dispersed water droplets, increasing emulsion stability and resistance to separation. Effective demulsification techniques are therefore essential to ensure crude oil quality, reduce corrosion and fouling, and improve overall process efficiency. Conventional chemical demulsifiers are widely used; however, their environmental impact, cost, and potential toxicity have motivated recent research toward environmentally friendly and sustainable alternatives.

Previous studies have demonstrated that crude oil emulsification and demulsification efficiency are strongly dependent on crude oil properties, particularly API gravity and the presence of natural emulsifying agents such as asphaltenes and resins (Kokal, 2005; Fingas et al., 1999). Commercial chemical demulsifiers are widely reported as effective, especially for light crude oils; however, their efficiency decreases for heavier crudes and raises environmental and economic concerns (Stewart and Arnold, 2008; Abdulrazzaq and Abdulkhabeer, 2022). Organic solvents and polymer-based treatments have shown limited and inconsistent performance, particularly for stable emulsions (Janssen et al., 2001). Although recent studies have explored green and natural demulsifiers with promising results (Zhang et al., 2021; Dhandhi et al., 2024), most investigations evaluated these materials independently. Therefore, the present study systematically compares chemical demulsifiers, organic solvents, polymers, and a natural material (MLX) under identical experimental conditions for different crude oil types.

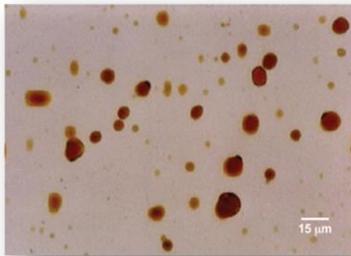


Figure (1): oil-in-water emulsion

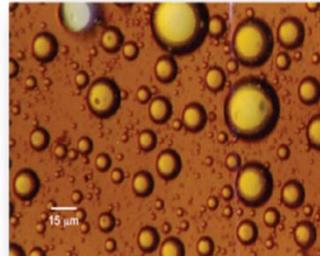


Figure (2) water -in- oil emulsion

### 1.1 Problem Statement

The formation of stable crude oil emulsions during production and transportation leads to increased viscosity, reduced separation efficiency, higher chemical consumption, and operational difficulties. Heavier crude oils, in particular, tend to form more stable emulsions due to their higher content of natural emulsifying agent

### 1.2 The importance of the study

Investigating emulsion separation is essential for improving crude oil quality, optimizing production costs, minimizing environmental impacts, and enhancing the efficiency of petroleum processing systems.

### 1.3 The Objective.

- 1-To evaluate the effectiveness of different solvents, polymers, commercial demulsifiers, and a natural material in breaking crude oil emulsions.
- 2-To analyze the influence of crude oil properties on demulsification performance.
- 3-To assess the potential of a natural material (MLX) as an environmentally friendly demulsification agent.

## 2. Methodology and Experimental Procedures

This study adopted a laboratory-scale experimental approach to evaluate the effectiveness of different demulsifiers agents in breaking water-in-oil (W/O) crude oil emulsions.

### Step 1: Crude Oil Selection

Two crude oil samples with different properties were used:

M.F crude oil (43.5° API), S.F crude oil (30.5° API)

Both samples contained relatively stable water-in-oil emulsions. Oil temperature and API gravity were measured prior to testing.

### Step 2: Preparation of Additives

The following materials were tested:

- 1- Commercial demulsifiers (demulsifiers CH-909 Demo AS and demulsifiers CH - 912 Demo AM)
- 2- Organic solvents (xylene and hexane)
- 3- Polymers (Polymer A and Polymer B), (Cellulose/poly (AAc-co-AAm)/Ag Nanocomposite).
- 4- Natural material (MLX)

All additives were prepared at concentrations of 0.25%, 0.5%, and 1%, depending on the material type.

#### **Step 3: Sample Preparation**

A volume of 100 mL of crude oil was placed into a graduated centrifuge tube. A measured amount of additive was added to achieve the desired concentration. The sample was gently mixed to ensure uniform distribution.

#### **Step 4: Centrifugation**

Samples were centrifuged at 1500 rpm, 60°C, for 10 minutes.

All experiments were conducted under controlled laboratory conditions to simulate field separation processes.

#### **Step 5: Phase Separation Measurement**

After centrifugation: The volumes of separated water, remaining emulsion, and oil phase were recorded. Separation efficiency was evaluated based on water separation and emulsion reduction.

### **3. Results and Discussion**

#### **3.1 Baseline Characteristics of Crude Oil Sample**

Prior to the application of any chemical or natural treatment, centrifuge tests conducted on the untreated crude oil samples (M.F and S.F) to establish baseline emulsion characteristics. The results confirmed the presence of stable water-in-oil emulsions in both samples, with the S.F crude oil exhibiting a significantly higher emulsion volume and lower free water separation compared to the M.F sample. This behavior can be attribute to the lower API gravity of S.F crude oil, which is typically associated with higher viscosity and a greater content of natural emulsifying agents such as asphaltenes and resins. Consequently, the S.F emulsion demonstrated greater resistance to phase separation.

#### **3.2 Effect of Demulsifiers (AS and AM)**

Commercial demulsifiers AS and AM were evaluated at concentrations of 0.25% and 0.5% to assess their efficiency in breaking crude oil emulsions. At a concentration of 0.25%, both demulsifiers exhibited excellent performance in the M.F crude oil, achieving complete water separation with no residual emulsion layer. This indicates a rapid and effective disruption of the interfacial film surrounding the dispersed water droplets. In contrast, the S.F crude oil showed limited separation, particularly with demulsifier AM, suggesting a stronger and more stable

interfacial film in heavier crude oil systems. Increasing the demulsifier concentration to 0.5% resulted in a noticeable improvement in water separation for the S.F sample. Demulsifier AS demonstrated superior performance compared to AM, yielding a higher volume of separated water and a reduced emulsion layer. These results highlight the strong dependence of demulsifier efficiency on crude oil properties and confirm that heavier crudes require higher chemical dosages to achieve effective emulsion breaking, shown Table (1), Figure (3).

**Table (1) summarizes the emulsion separation efficiency for Commercial demulsifiers AS and AM treatment methods**

Treatment Method	Concentration (%)	Crude Oil Type	Separated Water (mL)	Emulsion Layer (mL)	Separation Efficiency (%)
Commercial Demulsifier (AS)	0.25	M.F	6.0	0.0	100
Commercial Demulsifier (AM)	0.25	M.F	6.0	0.0	100
Commercial Demulsifier (AS)	0.25	S.F	3.5	11.5	23.3
Commercial Demulsifier (AM)	0.25	S.F	1.5	13.5	10.0
Commercial Demulsifier (AS)	0.5	M.F	6.0	0.0	100
Commercial Demulsifier (AM)	0.5	M.F	6.0	0.0	100
Commercial Demulsifier (AS)	0.5	S.F	8.0	7.0	53.3
Commercial Demulsifier (AM)	0.5	S.F	5.0	10.0	33.3

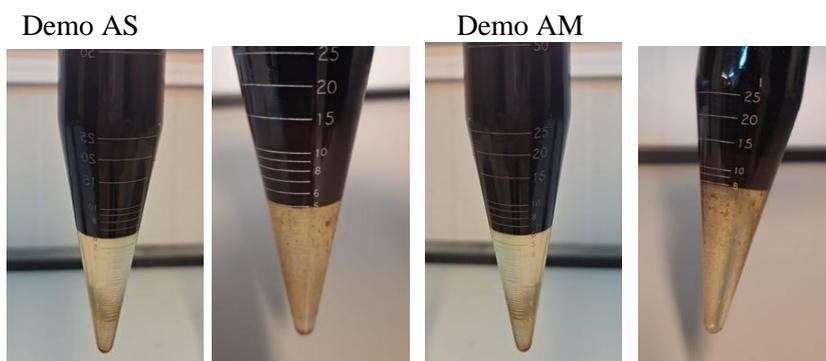


Figure (3) Result after addition Demo (AS and AM) - Concentration 0.5%

### 3.3 Effect of Organic Solvents (Xylene and Hexane)

The effectiveness of xylene and hexane as organic solvents was investigated at concentrations of 0.25% and 0.5%. At the lower concentration, both solvents showed moderate demulsification performance in the M.F crude oil, with xylene outperforming hexane in terms of water separation and emulsion reduction. However, their effectiveness significantly reduced in the S.F crude oil, where large volumes of stable emulsion remained after centrifugation. This limited performance may be attribute to the inability of low solvent concentrations to sufficiently dissolve or disrupt the rigid interfacial films present in heavier crude oil emulsions. When the solvent concentration increased to 0.5%, an improvement in separation efficiency observed, particularly for the M.F sample. Xylene demonstrated near-complete water separation, indicating its stronger solvency power and better interaction with aromatic components of crude oil. Nevertheless, even at higher concentrations, both solvents remained relatively ineffective in breaking the highly stable emulsion of the S.F crude oil, emphasizing the limitations of conventional solvents for heavy crude oil demulsification. Table (2), Figure (4).

**Table (2) summarizes the emulsion separation efficiency for Organic Solvents treatment methods**

Treatment Method	Concentration (%)	Crude Oil Type	Separated Water (mL)	Emulsion Layer (mL)	Separation Efficiency (%)
Xylene	0.25	M.F	5.0	1.0	83.3
Hexane	0.25	M.F	4.5	1.5	75.0
Xylene	0.25	S.F	3.0	12.0	20.0
Hexane	0.25	S.F	2.8	13.2	18.7
Xylene	0.5	M.F	5.8	0.2	96.7
Hexane	0.5	M.F	5.0	1.0	83.3
Xylene	0.5	S.F	4.0	11.0	26.7
Hexane	0.5	S.F	3.5	11.5	23.3

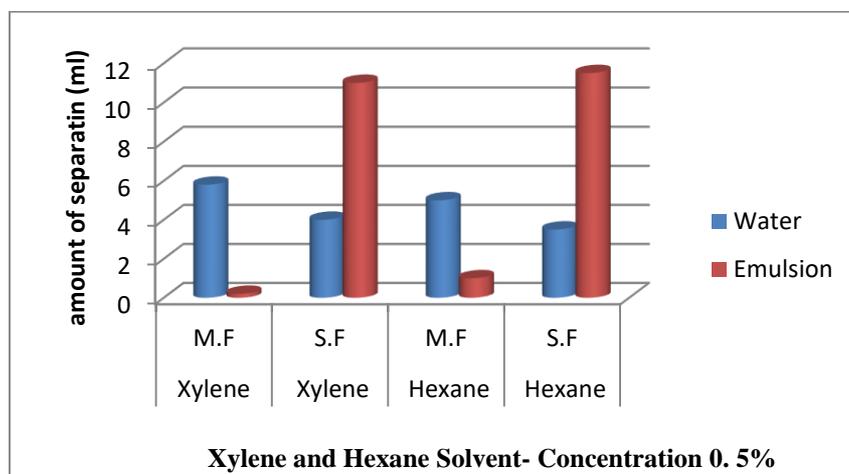


Figure (4) Results Effect Xylene and Hexane Solvent- Concentration 0.5 %

### 3.4. Effect of Polymers – A, B concentrations. (Cellulose /poly (AAc-coAAm) Ag Nano composite)

Effect of Polymers A and B Polymers A and B tested at concentrations ranging from 0.25% to 1% to evaluate their influence on emulsion stability. At lower concentrations (0.25%), both polymers exhibited limited effectiveness, particularly in the S.F crude oil, where only marginal water separation achieved. Polymer B consistently outperformed Polymer A, suggesting a stronger interaction with the emulsion interface or improved flocculation behavior. Increasing the polymer concentration to 0.5% and 1% enhanced water separation, especially in the M.F crude oil. Polymer B showed the highest efficiency across all tested concentrations, resulting in greater water recovery and a reduced emulsion layer. Despite this improvement, the polymers remained less effective in the S.F crude oil, indicating that polymer-based treatments alone may be insufficient for highly stable emulsions associated with heavier crude oils. Table (3), Figure (5), (6).

**Table (3) summarizes the emulsion separation efficiency for  
Polymers A and B treatment methods**

Treatment Method	Concentration (%)	Crude Oil Type	Separated Water (mL)	Emulsion Layer (mL)	Separation Efficiency (%)
Polymer A	0.25	M.F	1.0	5.0	16.7
Polymer B	0.25	M.F	2.2	3.8	36.7
Polymer A	0.25	S.F	0.5	14.5	3.3
Polymer B	0.25	S.F	0.6	14.4	4.0
Polymer A	0.5	M.F	1.6	4.4	26.7
Polymer B	0.5	M.F	3.0	3.0	50.0
Polymer A	0.5	S.F	0.6	14.4	4.0
Polymer B	0.5	S.F	1.0	14.0	6.7
Polymer A	1.0	M.F	3.0	3.0	50.0
Polymer B	1.0	M.F	4.0	2.0	66.7
Polymer A	1.0	S.F	1.0	14.0	6.7
Polymer B	1.0	S.F	2.2	12.8	14.7

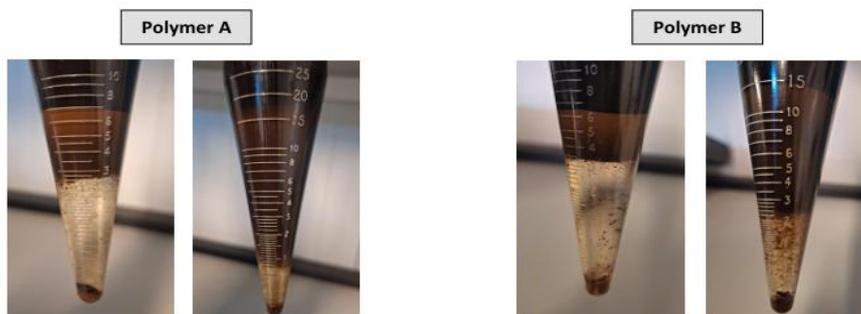


Figure (5) after addition Polymer A and B - Concentration 1%

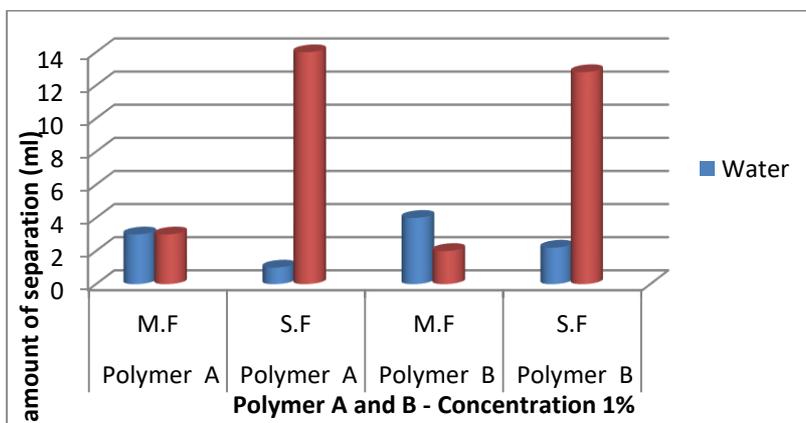


Figure (6) Results Effect of Polymers – A, B concentrations 0.5 %

### 3.5 Performance of Natural Material (MLX)

The natural material MLX evaluated as an alternative demulsification agent at concentrations of 0.25%, 0.5%, and 1%. At a concentration of 0.25%, MLX produced a measurable improvement in water separation for both crude oil samples, with a more pronounced effect observed in the M.F crude oil. Increasing the MLX, concentration to 0.5% significantly enhanced demulsification efficiency, as evidenced by increased free water volumes and a substantial reduction in the emulsion layer for both crude oils. At the highest concentration (1%), MLX achieved the most effective separation performance. The results indicate a clear concentration-dependent behaviour, where higher MLX dosages progressively weakened the emulsion stability and facilitated coalescence of water droplets. Notably, MLX demonstrated superior performance compared to polymers and organic solvents, particularly in the S.F crude oil, suggesting its strong potential as a natural and environmentally friendly demulsification agent.

The enhanced performance of MLX may be attribute to its ability to adsorb at the oil–water interface, displace natural emulsifiers, and reduce interfacial tension, thereby promoting droplet coalescence and phase separation. Table (4), Figure (7),(8),(9).

**Table (4) summarizes the emulsion separation efficiency for natural material MLX treatment methods**

Treatment Method	Concentration (%)	Crude Oil Type	Separated Water (mL)	Emulsion Layer (mL)	Separation Efficiency (%)
Natural Material (MLX)	0.25	M.F	1.5	4.5	25.0
Natural Material (MLX)	0.25	S.F	4.0	21.0	16.0
Natural Material (MLX)	0.5	M.F	3.0	3.0	50.0
Natural Material (MLX)	0.5	S.F	6.8	16.2	29.6
Natural Material (MLX)	1.0	M.F	4.2	1.8	70.0

Treatment Method	Concentration (%)	Crude Oil Type	Separated Water (mL)	Emulsion Layer (mL)	Separation Efficiency (%)
Natural Material (MLX)	1.0	S.F	10	13	43.4



Figure 7. Oil sample before addition (MLX) at Concentration 1%

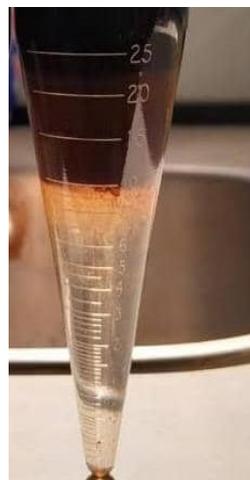


Figure 8. Oil sample after addition (MLX) at Concentration 1%

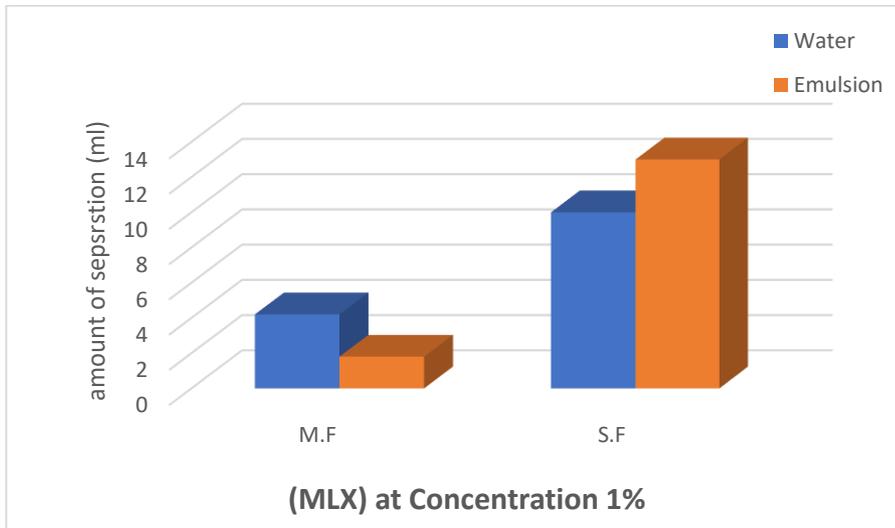


Figure (9) Results Effect Natural Material (MLX), concentrations 1 %

### 3.6 Comparative Discussion

Overall, the results confirm that demulsification efficiency is strongly influenced by crude oil properties, additive type, and concentration. Commercial demulsifiers remained the most effective treatment, particularly for lighter crude oils. Organic solvents and polymers exhibited limited effectiveness, especially for heavier crude oils with stable emulsions. In contrast, the natural material MLX demonstrated a promising balance between efficiency and sustainability, with performance improving consistently with concentration. These findings highlight the potential of natural materials as viable alternatives or supplements to conventional chemical demulsifiers in crude oil production and transportation systems.

## 4. Conclusion and Recommendations.

### 4.1 Conclusion

- 1- Demulsification efficiency strongly depends on crude oil properties, treatment type, and concentration
- 2- Commercial demulsifiers were the most effective, particularly for lighter crude oil
- 3- Polymers and organic solvents showed limited efficiency for heavy crude oil emulsions

- 4- The natural material MLX demonstrated promising performance, with efficiency improving significantly at higher concentrations
- 5- MLX represents a sustainable and environmentally friendly alternative to conventional demulsifiers.

#### 4.2 Recommendations

- 1- Evaluate the performance of the natural demulsified under actual field condition.
- 2- Investigate hybrid treatments combining MLX with low dosages of chemical demulsifiers
- 3- To apply the same experimental on different types of crude oil.
- 4- Future work should include economic and environmental assessment of MLX.

#### Acknowledgment

We would like to thank Allah, who has the greatest Grace on us.

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