Engineering and Technology Journal Vol. 37, Part C, No. 2, 2019

Fourth International Scientific Conference on Environment and Sustainable Development (4th ISCESD), Egypt, Cairo, 24-28 November 2018

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Received on: 01/09/2018
Accepted on: 10/01/2019
Published online:25/05/2019

Oil Removal from Oilfield Produced Water, North Rumaila by Combination Coagulation-Flocculation and Microfiltration Technique

Abstract- *The Southern Oil Company, which is operated in North Rumaila oilfield in Basrah/ Iraq, is one of the important companies which produced huge amounts of produced oilfield water. The aim of this study is to treat the produced water by hybrid methods: the process of coagulation-flocculation and microfiltration technique (ceramic membrane) to remove the oil content and improve the water quality to meet the allowable limit of reinjection into the reservoir. Poly-aluminum chloride (PAC), and Ferric Chloride ($FeCl_3.6H_2O$) coagulants were used separately and in combination with cationic polyelectrolyte (PE). After produced water was treated with different doses of coagulant, it was passed through the Microfiltration technique/ ceramic membrane (0.5µm) to reach the allowable limit for reinjection. It was found that the best value of oil content after passing through ceramic membrane is 0.2 mg/L at $FeCl_3.6H_2O$ dose (10 mg/L) combined with PE dose (0.6 mg/L), which was less than the allowable limit for re-injection, (5) ppm.*

Keywords- *Produced water; Coagulation; Flocculation; Ceramic Membrane, Oil Content.*

How to cite this article: Th.J. Mohammed, E.Sh. Awad and Th.A. Ahmed, "Oil Removal from Oilfield Produced Water, North Rumaila by Combination Coagulation-Flocculation and Microfiltration Technique," *Engineering and Technology Journal*, Vol. 37, Part C, No. 2, pp. 204-208, 2019.

1. Introduction

During the oil and gas production, produced water brought to the surface from underground formations as an incidental byproduct. It is the largest waste stream in the oil and gas exploration and production processes [1,2]. Produced water is a mixture of organic and inorganic materials [3]. Components of produced water vary considerably from location to another according to the geological formation, geological location of the field and types of hydrocarbon product being produced [4,5]. Produced water properties and volume can even vary throughout the lifetime of a reservoir [6,7].

Produced water is injected into oil and gas reservoir for multiple purposes such as a disposal, water flooding and enhanced oil recovery, and in some cases, hydraulic fracturing. Reuse of produced water could be a stable supply of water for fracturing, drilling, and completion that would minimize freshwater used [8]. Before Produced water disposed to the environment or re-injected, it requires appropriate technological, chemical, and bacteriological processing to meet the quality requirement [9]. Reinjection of treated produced water is more frequently applied, essentially because it's the only economic way to handle large volumes of water [6]. There are four methods of treatment produce water that has been used, i.e., physical, chemical, biological, and membrane-based treatment [10].

Coagulation is one of the important technology deals with water and wastewater [11-13]. Oilfield produced water is treated by the application of coagulation-flocculation treatment process. Coagulation and flocculation are defined as the process by which small particles in aqueous solution are destabilized by chemical addition, and aggregate together, forming larger particles known as flocs. With a neutral suspension, the flocculation rate can be enhanced, and the concentration of the given particle distribution in the solution can be reduced [14,15].

The aim of this study is to remove oil content from produced water and meet the allowable limit for re-injection by the hybrid method: the process of coagulation-flocculation and microfiltration technique (ceramic membrane).

2. Experimental

I. Characteristics of oilfield produced water

Oilfield produced water which used in this study was kindly provided by Petroleum Research and Development Center staff from DS1/ North Rumaila oilfield/ Southern Oil Company, which

https://doi.org/10.30684/etj.37.2C.1
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is situated in Basrah/Iraq. The location of the produced water sample is shown in Figure 1.
The characteristics of produced water include pH was around (7), EC (94900 µs/cm), TSS (333.2 mg/L), TDS (85410 mg/L, Turbidity (410.3 NTU), and oil content (36.4mg/L).

II. Materials and Methods

The hybrid processes for treating produced water consist of the coagulation-flocculation process by Jar- test (Model: Flocculator/ SW6) and filtration system (Nutshell filter and microfiltration technique/ceramic membrane filtration (Model: HK-U-M, Module: Tubular, porosity: 0.5 Micron).
Initially, a series of experiments were conducted with produced water in the laboratory using: The Flocculator/ SW6 jar tester, coagulation-flocculation process with variety doses of poly-aluminum chloride (PAC) ($Al_2(OH)_3Cl_3$), Ferric Chloride (FeCl3.6H2O) as primary coagulant and cationic poly- electrolyte (PE) as a coagulant aid to achieve maximum removal of oil content. The coagulants which are used in this study were provided by Al-Dura Refinery (Iraq).
Coagulant dosing was added to produce water and mixed 1 min under rapid mixing condition "flash mix" (150 rpm). Reduce the speed to the minimum required (50 rpm) to retain floc particles uniformly suspended during the "slow mix" of 20 min period. The oil content of supernatant liquor was measured and other required analyses after settling for 20 min.
After that, the optimum doses of the sample of produced water were filtered by Nutshell filter and then passed through ceramic membrane filtration (0.5 Micron) to achieve the allowable concentration range of the produced water constituents to facilitate the reinjection to the reservoir[12,16]. A schematic diagram of the filtration system used in this study is shown in Figure 2. Oil Content was determined by oil content analyzer (HORIBA/OCMA-350).
The filtration system consists of the following parts:

- Nutshell Filtration Column.
- Water Container.
- Water Pump.
- Pressure Gauge.
- Ceramic Membrane Filtration (Model: HK-U-M, Module: Tubular, porosity: 0.5 Micron)).

Permeate Container.

III. Experimental Procedure of the Membrane System

The general experimental filtration system procedure is as shown below:
1. Measurement of the oil content value of the produced water treated by the coagulation-flocculation process before filtration.
2. Filtration by nutshell filter to reduce the oil content value to less than or equal to 5 mg/L.
3. After filtration, the effluents are treated with ceramic membrane filtration (0.5 Micron) at maximum output pressure =1 bar and flow rate= 1.35 L/min to reduce the oil content value in order to reach allowable requirement range.
4. Measurement of the permeate water flux after the filtration experiment.
5. Measurement of the oil content after the filtration experiment.
The ceramic membrane is cleaned to be used for another run.

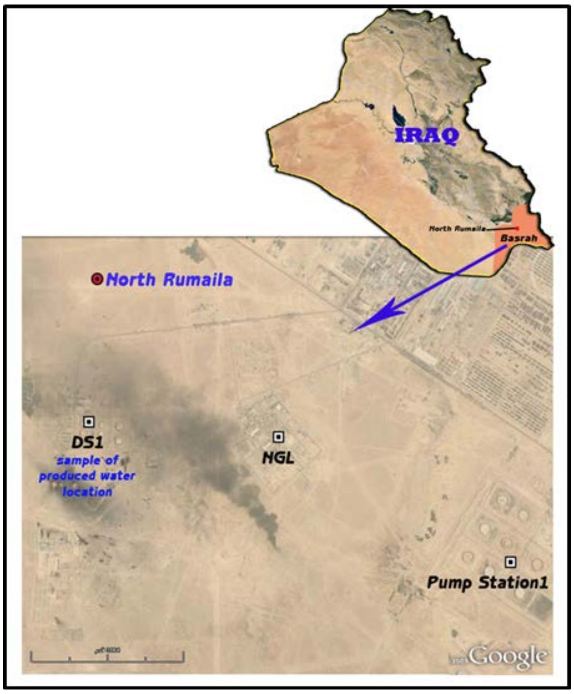

Figure 1: The site of produced water sample at North Rumaila oilfield

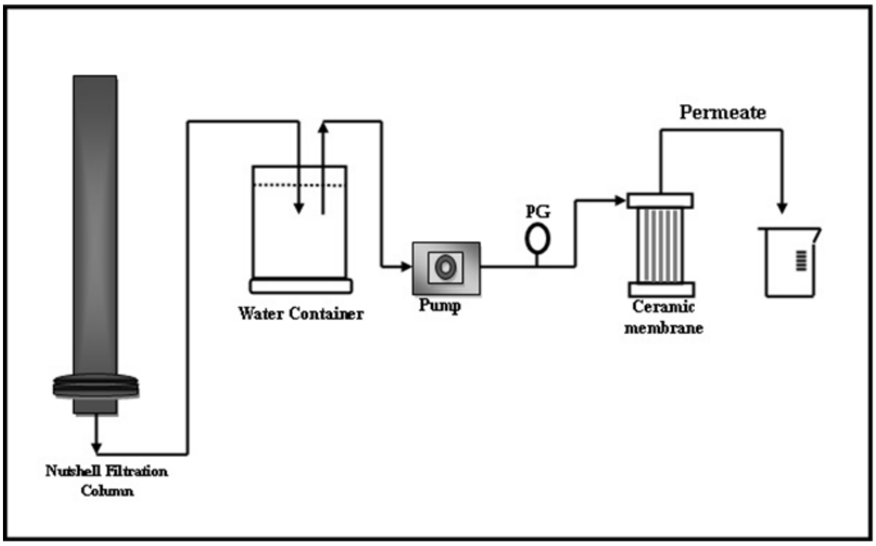

Figure 2: Schematic Diagram of the Filtration System for produced water treatment

3. Results and discussion

I. Oil removal by Coagulation-Flocculation Process

Different coagulants doses were used in the coagulation-flocculation experiment under Jar-Test with an initial oil content of (36.4mg/L). Figures 3 and 4 show coagulants used alone, oil content decreases with increasing dose of PAC and $FeCl_3.6H_2O$ until reaching the optimum dose of (80 and 20) mg/L, respectively.

The oil content reaches (2.7, 1.5, 2, 2.8) mg/L, when the optimum dose of PAC is 20 mg/L combined with (0.4, 0.6, 0.8, 1) mg/L of PE as shown in Figure 5, but the oil content is (5.2 and 1.6) mg/L and (2.1 mg/L) when the optimum doses of $FeCl_3.6H_2O$ reaches (15) mg/L at (0.4 and 0.6) mg/L of PE and (10) mg/L at (0.8) mg/L of PE, respectively, as shown in Figure 6.

The results show that the requirement of PAC dose is higher than $FeCl_3.6H_2O$ dose, but doses are lowered when combined with Polyelectrolyte (PE), Polyelectrolyte performs very well as a coagulant aid, particularly with $FeCl_3.6H_2O$.

The oil content decreases with increasing dose of PAC and FeCl3.6H2O until reaching the optimum dose, increasing doses cause an increase in oil content and reduction the removal efficiency, the over- dose causes destabilization that causes a weak attraction between droplets of oil and then causes a reduction in particles' settling velocity according to Stock law. Therefore the removal is decreasing [12].

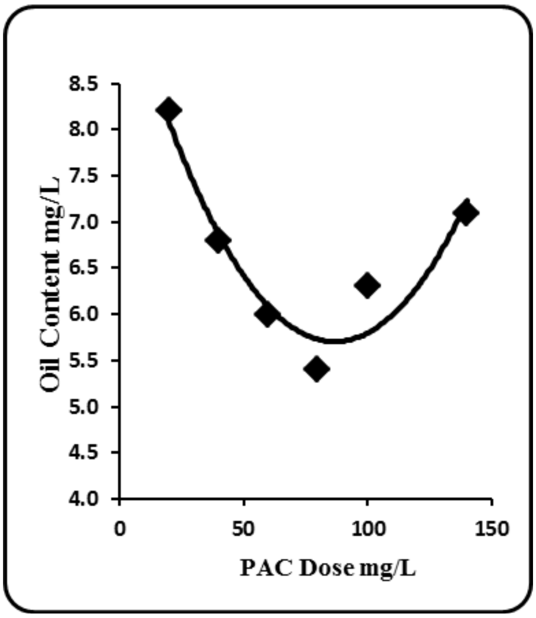

Figure 3: Oil Content removal by using PAC dose

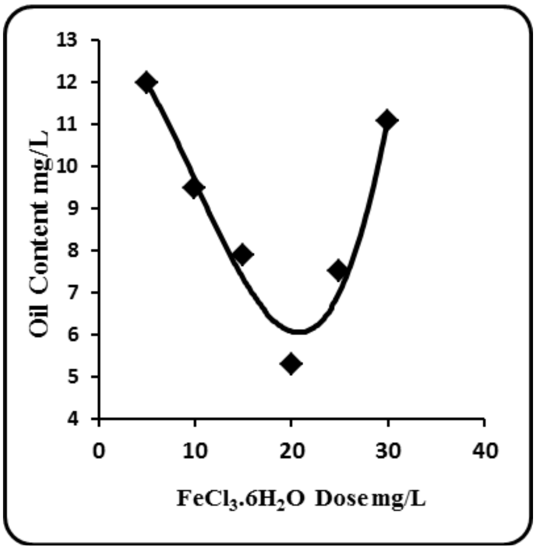

Figure 4: Oil Content removal by using FeCl3.6H2O dose

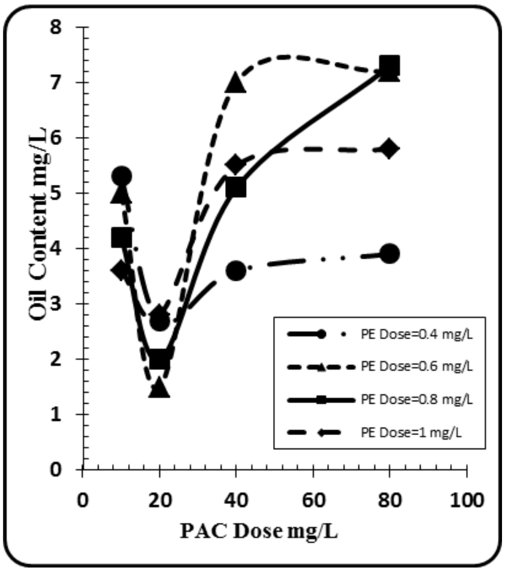

Figure 5: Oil Content removal by using PAC dose with the different doses of PE

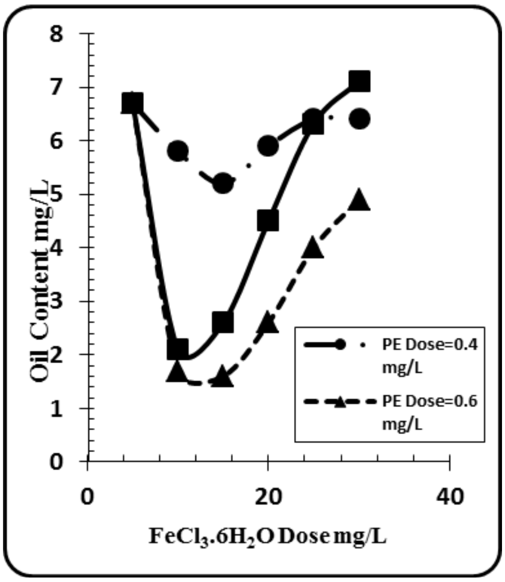

Figure 6: Oil Content removal by using FeCl3.6H2O dose with the different doses of PE

II. Oil Removal by Ceramic Membrane filtration

After produced water treated with different doses of coagulant–alone and combination- it would filter by Nutshell filtration to reduce the oil content and then passed through the ceramic membrane (0.5 Micron) to reach within allowable requirement range. Table 1 shows the best optimum doses selected to pass through the ceramic membrane and their symbols.

Table 1: The Best Optimum Doses Selected and Their Symbols used in membrane method

Doses	symbol
$FeCl_3.6H_2O$ Dose=15 mg/L, PE Dose=0.4 mg/L	M1
$FeCl_3.6H_2O$ Dose=15 mg/L, PE Dose=0.6 mg/L	M2
$FeCl_3.6H_2O$ Dose=10 mg/L, PE Dose=0.8 mg/L	M3
PAC Dose=20 mg/L, PE Dose=0.6 mg/L	M4
PAC Dose=20 mg/L, PE Dose=0.8 mg/L	M5

Figure 7 shows the oil content removal by the ceramic membrane. The 1^{st} column shows the oil content after the coagulation-flocculation process and then filtered by Nutshell filter which notices in the 2^{nd} column after that passes through ceramic membrane filtration (0.5 Micron) to reach the allowable rang for reinjection to the reservoir, which shows in the 3^{rd} column. The best value after passing through ceramic membrane (gives oil content= 0.2 mg/L) at $FeCl_3.6H_2O$ Dose=15 mg/L combined with PE Dose=0.6 mg/L [17].

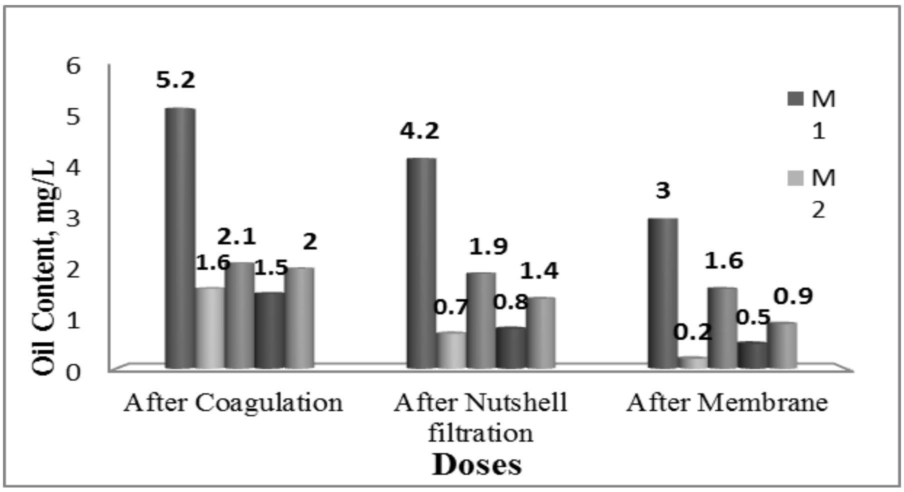

Figure 7: Oil Content removal by the filtration system.

4. Conclusions

- When using Cationic polyelectrolyte as a coagulant aid will reduce the PAC dosage required and increase the efficiency of removal.
- The coagulation power of $FeCl_3.6H_2O$, when used as a primary coagulant, seems to be more effective than PAC.
- The oil content removal in coagulation-flocculation treatment is equal to (5.4, 3 and 5.3 mg/L) respectively with optimum (PAC, PE and $FeCl_3.6H_2O$) doses (80, 2 and 20) mg/L.
- The best optimum combination of coagulant doses for oil removal efficiency is (20 + 0.6) mg/L and (10 + 0.6) mg/L for PAC and $FeCl_3.6H_2O$, respectively combined with PE.
- For ceramic membrane filtration method, which is used after the coagulation-flocculation treatment, the oil content could decrease to (3, 0.2, 2.6, 5, 4.3) mg/L with different optimum doses.

Acknowledgments

Many thanks were due to Petroleum Research and Development Center staff for supplying the produced water sample. In addition, we are grateful for Water Treatment Technology Center staff, Ministry of Science and Technology for their help.

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