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Current Challenges and Advancements on the Management of Water Retreatment in Different Production Operations of Shale Reservoirs

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Abstract: Nowadays, water savings on industrial plants have become a significant concern for various plants and sections. It is vitally essential to propose applicable and efficient techniques to retreat produced water from onshore and offshore production units. This paper aimed to implement the PFF (Photo Fenton Flotation) method to optimize the water treatment procedure, as it is a two-stage separation technique. The measurements were recorded for the HF (hydraulic fracturing) and CEOR (chemically enhanced oil recovery) methods separately to compare the results appropriately. To assure the efficiency of this method, we first recorded the measurements for five sequential days. As a result, the total volume of 2372.5 MM m^3/year of water can be saved in the HF process during the PFF treatment procedure, and only 20% of this required fresh water should be provided from other resources. On the other hand, the total volume of 7482.5 MM m^3/year of water can be saved in CEOR processes during the PFF treatment procedure, and only 38% of this required fresh water should be provided from other resources. Therefore, the total water volume of 9855 MM m^3 can be saved each year, indicating the efficiency of this method in supplying and saving the water volume during the production operations from oilfield units.

Keywords: water treatment; CEOR; HF; PFF method; water saving

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1. Introduction

Regarding the enormous demand of various industrial plants for water supplies and the dependency of human life on water, it is essential to be more conservative and careful about its consumption [1–5]. Moreover, it can cause droughts worldwide due to the lack of water supply to feed forests [6–10]. This is the main issue that researchers have tried to address in current decades, to increase the efficiency and accuracy of water treatment methods [11–13]. One of the most practical ways to reduce the water demand for industrial plants is to treat produced water to eliminate virtually the high water supply expenses from other resources [14–18]. For example, petroleum industries are one of the largest industrial plants worldwide that require water for their operations [19,20]. As the produced water contains hazardous materials and can pose significant environmental problems, it cannot be reused without retreatment [21–30]. Therefore, the use of treated water to continue the operations should be strictly promoted by the World Health Organization to [31–40]. These hazardous materials consisted of solid and heavy metals, chemical agents in produced water that might be highly toxic to the environment [41–51].

There are two main processes in petroleum industries that require large quantities of water to proceed with operations [51–55]. These procedures aim to increase the oil production to supply the necessary demand for industrial plants to crude oil [56–58]. Hydraulic fracturing is an essential process in petroleum industries that requires a large volume of water to create a fracturing fluid [59–63]. In this process, oil production has been increased by enlarging the previous and tight pores or creating new pore channels to simplify the oil mobilization through porous media [64–68]. As the fracturing fluid has been returned to the surface after the HF process, it should be treated in surface treatment facilities to remove solid and chemical particles in flow backwater. Therefore, an optimum and efficient method would be essential to provide the maximum water savings in the treatment performances [69–71]. These water savings can ensure the survival of several inhabitant and reduce the unnecessary expenses of freshwater supply. Another production operation that required water to continue its processes is CEOR, as water would be an essential part of preparing chemical agents such as polymers, foams, and surfactants [72–74]. The reason for this concerns the aqueous solution that needs to be provided for CEOR methods, as polymers and surfactants are in the form of powders [75–77]. Therefore, to control the processes in underground formations, it is crucial to use chemical agents as aqueous solutions [77]. Due to chemical agents' inflow backwater, which might be combined with reservoir chemical components, it is necessary to have adequate separation and treatment processes to remove most of these components [78]. This can help eliminate the hazardous impact of these materials when disposed of in the environment. The PFF method is considered the applicable method for onshore and offshore plants, as they treat water in two primary and secondary stages in different sections [79–84].

Coonrod et al. (2020) proposed an analytic review on the efficient and applicable treatment processes for Bakken shale oilfield to define the proper technique in water treatment performances among various separation and treatment techniques. They found that the U-PW method is the most applicable and efficient technique for water treatment in shale oilfields, rather than floatation, desalination, and oxidation methods [85]. Due to the lack of experimental and field application data for water treatment processes, especially in onshore plants, we aimed to implement the PFF method to optimize the water treatment procedure as a two-stage separation technique. The measurements were recorded for the HF and CEOR methods separately to compare the results appropriately. To assure the efficiency of this method, we first recorded the measurements for five sequential days.

2. Methods

One of the most efficient and applicable water treatment processes in onshore and offshore drilling operation plants is the PFF (Photo Fenton Flotation) method. In this method, ultraviolent hydrogen peroxide radiation was simultaneously implemented to treat the produced water from production wells. In this method, the degradation of organic pollutants was done by the generation of hydroxyl radicals during the processes, and it can help treat the water. Furthermore, the following steps were done sequentially to retreat the water during the production operations, and the facility services should be near the production wells to virtually eliminate the unnecessary expenses of water transfer (see Figure 1).

(1) Produced flow-back water from production wells was transferred to the system. Specific gauges measured the volume of produced water to measure the final stages of water retreatment accurately. The produced water was transferred to API (American Petroleum Institute) separators to separate solid phases, gas, water, and other simple components from produced water. This stage is called primary treatment.

(2) Then, the water separated at this stage reacted with chemical additives to adsorb small ions and settle them.
(3) Next, the treated water is moved to the dissolved gas floatation section, which can cause the elimination of the gas content by the floatation method in the system. Again, a chemical additive has been added to the system in this section to settle the ions.
(4) In this stage, the treated water moves toward the metal removal section consisting of several screen packs with various meshes.
(5) Then, it is transferred to the sand filtrations section to eliminate the micro- and nanoparticles in the water content. This section is known as the second separation section, and the treated water has been measured by sensitive gauges that can be used in the calculation of treated water.

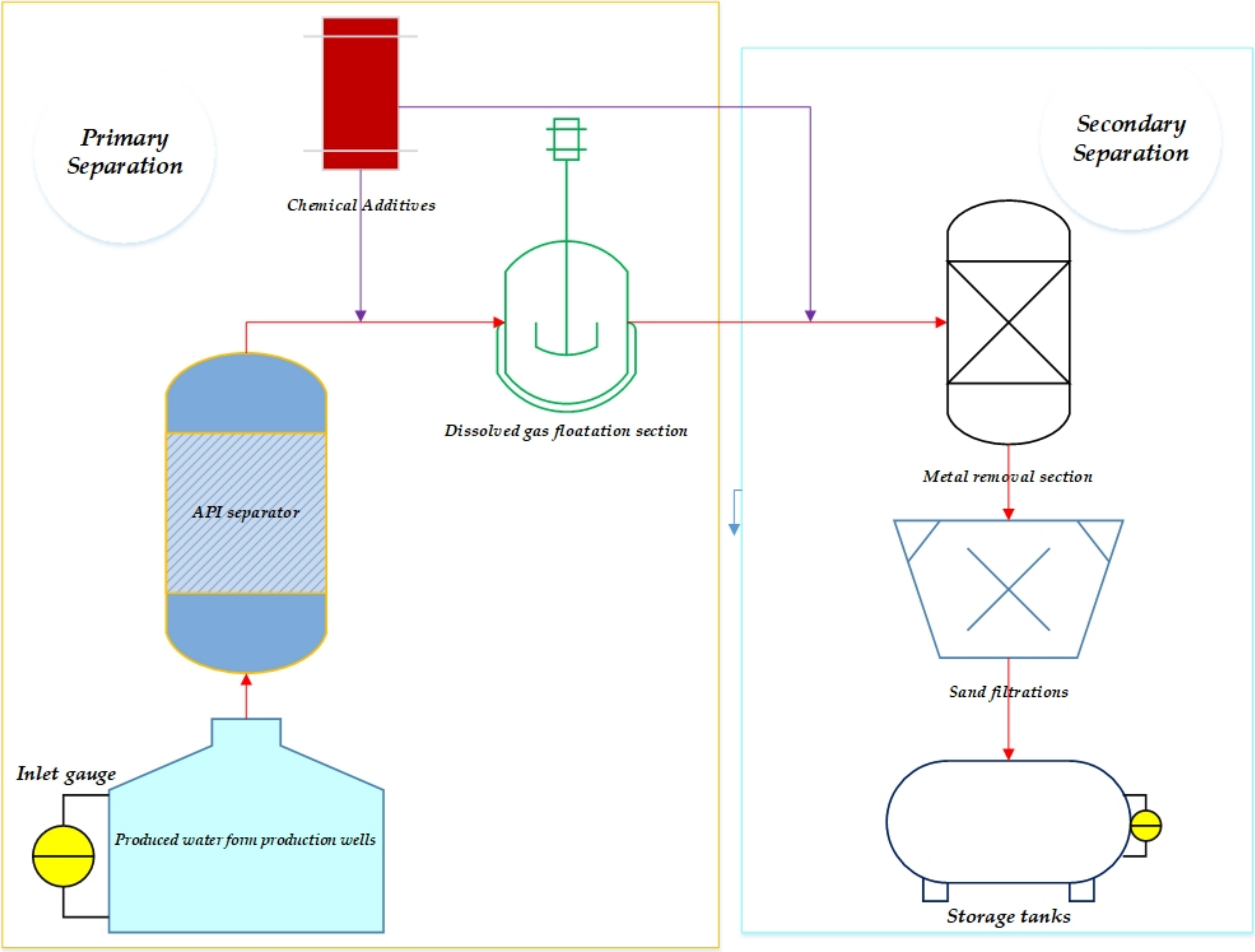

Figure 1. PFF method to retreat produced water.

In the PFF method, we used gauges at the inlet and outlet of the system to measure produced water. We repeated the measurements several times to check the accuracy of the implemented system. Therefore, the total volume of treated water is calculated as the following equation. It should be noted that produced water after each process is calculated separately to distinguish the efficiency and adequacy of the PFF treatment method.

$$\text{Total treated water (MM m}^3\text{)} = \text{(Produced water before entering the primary separation)} - \text{(Produced water after the secondary separation)} \quad (1)$$

Finally, the total treated water is the summation of the treated water in each method to overview the total produced water and how much of this water volume can be saved to remove the required freshwater.

3. Results and Discussion

3.1. Water Treatment from HF Method

Regarding the water supply requirement for the commencement of the HF procedure, it is vitally essential to estimate the required water not to postpone the operations. Therefore, production engineers should adequately define the required water, as water is the central part of fracturing fluid. In this part, we have focused on the water retreatment after the HF procedure to estimate how much water volume can be saved and how much freshwater volume is required in the system. First, we divided the wells into oil and gas wells to be more distinguishable for each well. Then, as the treatment process may take a long time, we recorded our measurement for five sequential days by entering the specific produced water volume in the PFF system to check the system's accuracy. This is shown in more detail in Table A1, in the Appendix A. Next, the average volume after these five sequential daily measurements is calculated and statistically depicted in Table 1.

Table 1. A summary of water treatment savings for HF procedure.

Well no.	Avg. Pro. Water in PFF System (MM m^3/Day)	The Total Volume of Required Water (MM m^3/Day)	Saving Water (MM m^3/Day	Saving Water (MM m^3/Year)	Saving Water (%)	Required Freshwater (%)
W_Oil#A	3.25	4.5	1.25	456.25	72	28
W_ Oil#B	4	5.25	1.25	456.25	76	24
W_ Oil#C	4.75	6	1.25	456.25	79	21
W_ Oil#D	3	4	1	365	75	25
W_ Oil#E	3	3.5	0.5	182.5	86	14
W_Gas#F	3.5	3.75	0.25	91.25	93	7
W_ Gas#G	2	2.5	0.5	182.5	80	20
W_ Gas#H	2.25	2.75	0.5	182.5	82	18
Total volume	25.75	32.25	6.5	2372.5	-	-
Average Percent	-	-	-	-	80	20

As shown in Table 1, in this field, the total volume of 2372.5 MM m^3 of water can be saved during the PFF treatment procedure, and only 20% of this required fresh water should be provided from other resources. It is indicated that this method is efficient in onshore and offshore plants.

3.2. Water Treatment from CEOR Methods

CEOR (Chemical enhanced oil recovery) methods are considered methods to improve the oil production from underground formations. In this part, we calculate the treated water for each well (see Table 2). As shown in Table 2, in this field, the total volume of 7482.5 MM m^3 of water can be saved during the PFF treatment procedure, and only 38% of this required fresh water should be provided from another resource. It is indicated that this method is efficient in onshore and offshore plants.

Table 2. A summary of water treatment savings for the CEOR procedure.

Well no.	Avg. Pro. Water in PFF System (MM m^3/Day)	The Total Volume of Required Water (MM m^3/Day)	Saving Water (MM m^3/Day	Saving Water (MM m^3/Year)	Saving Water (%)	Required Freshwater (%)
W_Oil#A	10	15.5	5.5	2007.5	65	35
W_ Oil#B	10	13.75	3.75	1368.75	73	27
W_ Oil#C	5.25	13.25	8	2920	40	60
W_ Oil#D	3.75	5	1.25	456.25	75	25
W_ Oil#E	4.75	6.75	2	730	70	30
Total volume	33.75	54.25	20.5	7482.5	-	-
Average Percent	-	-	-	-	62	38

The summary of results was shown schematically in Figure 2. As shown in Figure 2, due to the large volume of chemical agents in CEOR methods mixed with formation chemical components, the value of saving water is lower than in the HF processes.

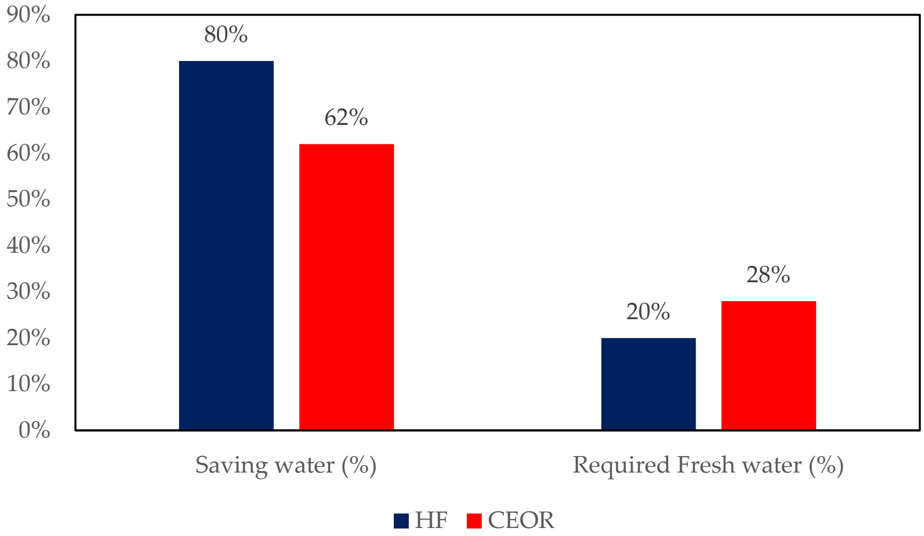

Figure 2. Summary of results.

4. Conclusions

The PFF (Photo Fenton Flotation) treatment method is considered efficient and applicable to improve water retreatment processes, as providing sustainable freshwater management is essential in onshore and offshore plants. To assure the efficiency of this method, we first recorded the measurements for five sequential days. As a result, the total volume of 2372.5 MM m^3 of water can be saved in the HF process during the PFF treatment procedure, and only 20% of this required fresh water should be provided from other resources. On the other hand, the total volume of 7482.5 MM m^3 of water can be saved in CEOR processes during the PFF treatment procedure, and only 38% of this required fresh water should be provided from other resources.

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Appendix A

Table A1. Daily measurement of produced water in PFF system in HF process in MM m^3.

Well no.	Day #1	Day #2	Day #3	Day #4	Day #5
W_Oil#A	3.12	3.24	3.04	3.49	3.63
W_ Oil#B	3.89	4.17	4.11	3.94	4.35
W_ Oil#C	4.62	4.52	4.86	4.93	4.58
W_ Oil#D	2.78	3.16	2.89	3.06	3.3
W_ Oil#E	3.01	2.84	2.94	2.93	3.13
W_Gas#F	3.43	3.56	3.24	3.37	3.32
W_ Gas#G	1.86	1.75	1.89	1.94	1.97
W_ Gas#H	2.14	2.35	2.28	2.23	2.08

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