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Research Paper

Comparison of Available Water Resources in terms of Formation of Mineral Deposition for Injection into a Petroleum Reservoir

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Abstract: Recently, water injection has been widely studied as one of the most popular enhanced/improved oil recovery methods. Most of the studies focus on low salinity and seawater injection, emphasizing the quality of the injection fluid. In addition, receiving the required quantity of injection water and high-quality injection fluid is crucial. Produced water with oil and urban wastewater can be regarded as appropriate resources for water injection projects to mitigate the environmental concerns and the cost of water treatment. This study examines several water resources suggested for injection into an oil reservoir near the Persian Gulf to find the optimal choice. The studied resources are low-salinity water, seawater (from the Persian Gulf), produced water, and urban wastewater. Injection fluid quality, compatibility with formation brine, scale formation, and usability were the primary factors considered when selecting the optimal water resource. Accordingly, geo-chemical software *OLI Scale Chem* was used for compatibility check and estimation of scale type and amount. As a result, the least amount of scale formed after urban wastewater injection, whereas seawater was the most incompatible water source. It should be emphasized that various non-technical factors, such as the climate of the region, the water transmission route and associated costs, economic conditions of the country, environmental concerns, and the priority of wastewater usage may significantly impact resource selection.

Keywords: Inorganic scales, Water compatibility, Water injection, Enhanced oil recovery, Improved oil recovery.

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INTRODUCTION

The best EOR/IOR water resource selection to inject into the reservoir has always been challenging in the petroleum industry. This challenge refers to injectivity maintenance, which depends on the availability of injection resources in the desired amount and quality. Seawater and low salinity are conventional injection water resources in different water resources that have been widely investigated in the last decades. However, based on environmental issues and the cost of treatment, urban wastewater and produced water could be other candidates to inject. The variety and availability of these water resources are discussed below:

- Sea water (SW): 72% of the ground is covered by water, of which 97% is saline seawater. An enormous seawater source makes it the first candidate for offshore and coastal field's water injection, even though it is practically problematic because of its high sulphate content.
- Low salinity water (LSW): Water with salinity lower than 4000 mg/l is considered low salinity water. It increases the recovery factor by wettability alteration, microscopic displacement, and residual oil saturation reduction. Recent studies show that lowering salinity is not the only way to enhance oil recovery; increasing some ion contents also helps wettability alteration. LSW is usually made by desalination and treatment of saline water- which costs too much- or dilution of high salinity waters by valuable fresh water. The high cost of low salinity water supply deducts the attractiveness of this method.
- Urban wastewater (UWW): Disposed water from cities, industries, and agriculture is wastewater. The quality of wastewater, which may contain suspended solids (between 350-1200 mg/l), dissolved minerals and components (250-1000 mg/l), micro-organisms, nutrients (e.g., nitrogen and phosphorus), heavy metals, and microscopic pollutions -depending on its source- is varied [1]. High-contaminated wastewaters are very problematic and may cause severe harm to the environment and public health. Due to low mineral and dissolved solid content (less than 4000 mg/l), this vast water source can be classified as low salinity waters with low gathering and treatment costs compared to LSW. Besides, according to global data, wastewater volume is 20 times more than the produced water, and therefore, it is more accessible, especially for reservoirs near the cities.
- Produced water (PW): Many wells produce water as a by-product during oil and gas production. According to the records, the water-oil ratio was almost 3 in 2018. In other words, for 98 million barrels of oil production, 300 million barrels of water were produced. This amount is expected to be increased up to 12 barrels of water per barrel of produced oil by 2025 [2]the characteristic, and the production of produced water are considered to facilitate the understanding of its physics, chemistry, affecting factors, and corresponding impacts. The major produced water management methods, including produced water minimization, produced water reuse/recycling, and produced water disposal, as well as legal frameworks, policies, and regulations related to produced water from onshore and offshore oil and gas fields, are described. Commonly applied produced water treatment technologies in the oil and gas industry, corresponding technical details, and advantages and disadvantages are evaluated. Produced water reinjection (PWRI. It should be noted that the produced water directly relates to the production years of the reservoir. Therefore, a high-produced water-oil ratio is not expected in the green fields and those in their early production stages.
- In addition to the availability of water resources, water quality is crucial, too. Scale generation, flow assurance, formation damage, and water treatment cost are some operational challenges of injection water quality. The scale formation in porous media is the most significant factor that limits an injection project.
- Scaling is the deposition of inorganic salts due to the supersaturation of minerals in water, which may close the fluid channels and reduce the water injectivity. Scale formation depends on thermodynamic conditions, such as pressure, temperature, pH, and changes in water composition. Accordingly, the water may become supersaturated at reservoir conditions in case of incompatible waters, and the scales start to precipitate [3]. Therefore, compatibility tests and simulations are recommended to check the probability of scaling. This study uses a geochemical software as a fast and reliable tool to investigate fluid compatibility by setting their properties and defining the desired conditions [4]. The software checks the stability of equilibrium and fluid saturation conditions of the constituent ions. It offers a vast database of chemical reactions that could take place at reservoir or near-surface conditions.

METHODS

This study investigates water injection into an oil reservoir in the southern region of Iran. According to the geographical position of the field, in the vicinity of the Persian Gulf and the access to the urban wastewater from the nearby city, four different candidates are available as injection fluid: produced water, Persian Gulf water, low salinity water (10 times diluted Persian Gulf water), and urban wastewater. The compositions of injection water candidates and the formation water are summarized in Table 1.

Table 1. Composition of injection water candidates and the formation water

Property/water sample	Unit	Produced water (PW)	Persian Gulf water (PGW)	Urban wastewater (UWW)	Low-salinity water (LSW)	Formation water (FW)
pH	_	5.3	8.04	7.22	7.88	6.1
NH_3-N	mg/L	Na	Na	24.7	Na	Na
HCO_3^-	mg/L HCO_3^-	138	158	Na*	15.8	348
SO_4^{2-}	mg/L SO_4^{2-}	203	3236	235.5	323.6	465
Cl^-	mg/L Cl^-	125000	21974	387	2197.4	131000
NO_3	mg/L	Na	Na	2	Na	Na
P	mg/L	Na	Na	14	Na	Na
SiO_2	mg/L	Na	Na	26	Na	Na
Ca^{2+}	mg/L CaCO3	11400	391	126	39.1	7000
Mg^{2+}	mg/L CaCO3	1900	1516	36	151.6	1800
Na^+	ppm	61000	11985	88.78	1198.5	70000
K^+	ppm	850	464	25.2	46.4	980
Sr^{2+}	ppm	1030	0	NA	0	400
TDS	mg/L	201553	39750	1226	3975	212000

*The bicarbonate amount was not reported in the wastewater, butestimated with the software

The compatibility tests were conducted using the geochemical simulator *Oli ScaleChem* in nine ratios to establish different mixing ratios of reservoir and injection fluids (0.1 to 0.9 with 0.1 steps) at reservoir temperature and pressure (205 F and 3700 psi).

FINDINGS AND ARGUMENT

Based on the availability of injection fluid amounts, candidates were nominated with two assumptions. In the first assumption, the injection fluid is reachable satisfactorily, so the pure injection fluid candidates are simulated.

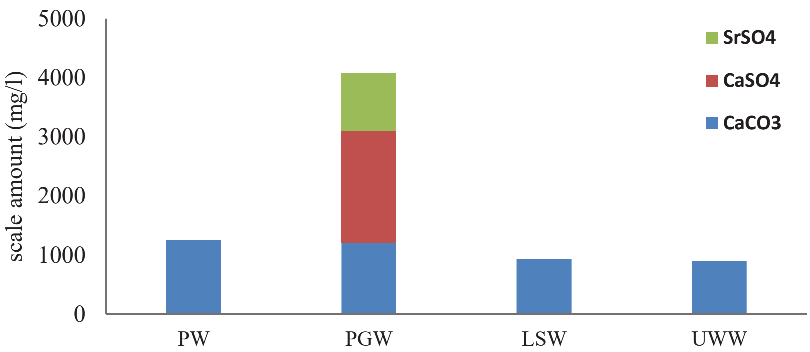

Figure 1. Total scale generation of injection candidates with formation water in different ratios

Figure 1 shows the total scale generation of when the pure injection fluid candidates are mixed with formation water in different ratios. Simulation results demonstrate comparable high compatibility of low salinity water and urban wastewater and incompatibility of Persian Gulf water with formation water. The high scale prediction of PGW mixture with formation water is due to the high concentration of sulfate ion in PGW and its sensitivity to highly concentrated divalent cations, like calcium and strontium, in formation water.

In the second assumption, when the water resource is not reachable at the desired volume, mixing of resources is the replacement strategy. This study investigated an equal ratio of coupled injection candidates (0.5-0.5 ratio) to estimate the scale precipitation. Figure 2 shows the total scale generation of coupled injection candidates with formation water in different proportions.

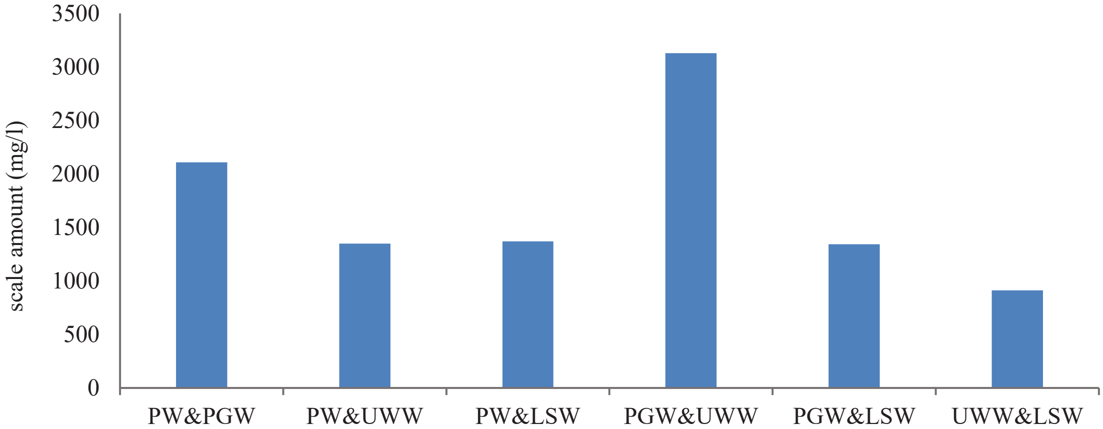

Figure 2. Total scale generation of coupled injection candidates with formation water in different ratios

Results show that mixed injection candidates containing Persian Gulf water (PGW) are the most incompatible injection waters with formation brine.

CONCLUSIONS

One of the crucial challenges across water injection projects is injectivity maintenance, specifically the compatibility of the injection water and the formation brine. Urban wastewater and low-salinity water are the most common, and Persian Gulf water and its mixture with other injection candidates are the least compatible waters. Although the produced water scale content was 50 times more than low-salinity water and 200 times more than urban wastewater, its scale generation is only about 30% more than urban wastewater or low-salinity water and formation water mixtures. This makes the produced water an attractive injection candidate based on operational and environmental issues.

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