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Evaluation of Main Pay- Zubair Formation after Operations Re-Injection of Produced Water Directly In Rumaila Oil Field Norths under Matrix Condition

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Abstract

The water injection program is a key part of Rumaila oilfield long-term development plan to raise pressure levels in reservoirs. This water injection program has involved project of produced water re-injection (PWRI) directly. Although PWRI is most economical method for disposal of produced water and reduces environmental pollution risks but it can causes impairment in formation permeability due to contain it on suspended and dissolved solids that can plug porous media. Therefore, it is essential conduct fluid-rocks compatibility experiments and analysis to evaluation PWRI. The experimental work was carried out in Department of Laboratory and Quality Control in Basra Oil Company, using waterflooding apparatus. The compatibility experiments were applied on five core selected from Main Pay - Zubair formation that has very high permeability with 40 liter produced water at North-Rumaila oilfield. The main purpose of this work is evaluation of PWRI by studying the reduction of permeability(formation damage). The maximum damage degree is 71% and the minimum damage degree is 55% with average value 68.2%. The main causes to impairment permeability are present high concentration from suspended solids in PW. The damage is start from maximum degree near wellbore and gradually decreasing away from injection well and the permeability start jump up. The damage zone is propagate symmetrical around axial wellbore injector and connect together formed roughly circular dish. In this paper we establish table of monitor for help to minimize formation damage. Based on these results, we can concludes, direct injection of produced water into Zubair formation without surface treatments or washing of formation or acidizing treatment or injection under fracture conditions causes formation damage and increases with time.

Keywords: Produced water re-injection, Impairment permeability, Formation damage, Damage zone, Monitor damage.

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1. Introduction

Water flooding are known and widely common secondary recovery method in oil industry, where water is injected into the oil field, usually to increase pressure, stimulate production and keeping the same of production rate and the pressure for the long term. There are two behaviors in water injection; fracture injection when well is operated at high pressure injection that would create fractures, and matrix injection when well is operated at low fracture pressure. The water quality plays an important function in operation injection because the high quality lead to reduce damage in reservoir formation and poor quality will result in lost oil production. For achieve water that have sufficient quality may be it need costs that quality can become excessive [1-8].

Formation damage is a generic terminology referring to the any reduction (impairment) permeability in the near-wellbore region. Total dissolved solids and total suspended solids (solids and oil droplets) in the injection water are two main reasons that cause formation damage. Two mechanisms are often to occur damage, the smaller suspended solids enters into a porous media and form an filter cake on internal surface of porous, while larger particles will deposit on the surface and form an external filter cake. Highly compressible filter cake closes the throats of pore. In each of these scenarios, the permeability near the well decreases and injectivity begins to decline. There are more sources of water streams are injection in oil reservoir, 1) surface water, fresh water (river or lake) and saline water (seawater).

In the past, fresh water was commonly used in waterflood, but because of increasing scarcity, fresh water will not generally be a viable source. 2) Produced water which is defined as contaminated water trapped in the reservoir rock and brought from underground reservoirs up along with oil or gas during production. It is characterized as highly saline water which is comprised of formation water.

The most injection projects use fresh or saline or produced water depending on the geographical location and availability. Produce water is one of the most important water sources to recovery of oil. Reusing produced water can reduce the demand for fresh water and change the waste into usable water resources. Produced water reinjection (PWRI) is economic method to disposal of waste water that environmentally acceptable solution and maintenance of reservoir pressure to enhanced oil recovery. The main problems are impairment of permeability which plugging of pore space by suspended solids in produced water. Suspended solids in

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injection water are originate from silts, clays, different types of scales, products of bacterial activity, or erosion of rock during oil production. Removal of all suspended solids from injection water is an expensive and economically unfeasible process. To minimize the effects of suspended solids on formation, it is necessary to determine an impairment permeability of formation and selected optimize the water treatment process [9-14].

Compatibility experiments are laboratory testing, which play an important role in determining formation damage. It is depended on concept of waterflooding for core. Compatibility experiments can be classified into two groups: fluid-fluid compatibility and fluid-rock compatibility. The fluid-fluid interactions include, emulsion blocking or inorganic and organic deposition. But the fluid-rock interactions include mobilization, migration and deposition of suspended solids [14].

There are old local studies in Basra Oil Company (Department of Research and Quality Control).It were limited on compatibility test between river water (Garmat ali and Euphrates rivers) and rocks for difference formation reservoir [15-17]. The main purpose of this work is experimental evaluation of operation produces water reinjection directly by measured impairment permeability of Zubair formation after injection.

1.1 Concept of permeability

Permeability is the ability of the rock to allow fluid movement through its interconnected pores. Permeability is a characteristic of a porous medium .The measurement of the porosity and permeability property of reservoir are important in terms of reservoir studies, because it entered into geological modeling and formation damage [18]. The first to give a mathematical expression to permeability was Henry Darcy in 1856, which is called Darcy's law. If incompressible fluid flow horizontal linear by rate cm^3 / sec through a cylindrical reservoir rock of length L and its cross-sectional area, the permeability is given by the following relationship [19, 20]:

$$k = \frac{Q\mu\, L}{A\, \Delta p} \qquad (1)$$

Unit of measurement k is called Darcy, which is defined as the rate of fluid flow has viscosity in (cp) with a volume of one cubic centimeter (1 cm^3) per second (1sec) through a cross section of one square centimeter (1 cm^2) with a pressure gradient of one atmospheric pressure per one

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centimeter of length (atm / cm). For reservoir rocks permeability can be classified as in Table 1[16].

Table (1) Reservoir rocks permeability classified

Permeability Value (md)	Classification
<10	Fair
10 – 100	High
100 – 1000	Very high
>1000	Exceptional

1.2 Mathematic expression of formation damage

Formation damage factor can be expresses mathematically by various terms such as skin factor, relative change of permeability, relative change of viscosity, relative change of effective fluid mobility, relative change of flow rate (damage ratio), and flow efficiency. Formation damage is defined the reduction of permeability of the reservoir formation [7, 21]:

$$F_D = \frac{K_i - K_f}{K_i} = 1 - \frac{K_f}{K_i} \qquad \because\ K_f \leq K_i \rightarrow 0 \leq \mathrm{F_D} \leq 1 \qquad (2)$$

K_i is the primary permeability before damage, K_f is the permeability after damage. From equation (2), we fined two cases:

- $F_D = 100\%\ @\ K_f = 0 \quad full\ damage$
- $F_D = 0\ @\ K_f = K_i \quad non - damage$

2. Study of Area

History: The Rumaila is the biggest oilfield in Iraq that was discovered in 1953 and in 1972 started in operation; it is a 6th globally, with oil reserves of about 17 billion barrels. Rumaila fields are divided into two parts: North Rumaila and Southern Rumaila.

Location and surface area: The Rumaila oilfield is located of about 50 km to the northeast of North Luhais oilfield in the Basrah city, southern Iraq. The field lies approximately between (47º, 14` 47º, 19`) Latitude and (30º, 13` 30º, 24`) Longitude. Rumaila oilfield is located 50 km to the west of Basra covering an area of 1600 km^2.

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Geology: The main reservoir structures of the field are Zubair (Main Pay) formation, Upper Shale reservoir, and the Mishrif reservoir. The Zubair Formation is the main producing zone in the Rumaila oilfield. Top of Zubair Formation in Rumaila Oil field oil field appears at depths ranging between 3100-3170 m and its total thickness in the type section reaches about 440 m in well RU-167. It consists of interbedded sandstone, siltstone and shale, and sometimes with carbonate rocks especially in the upper part of the formation.

Drive system: In an attempt to increase the production of oil from the main pay reservoir and maintain the reservoir pressure by achieving better water injection plan, a water flooding project was implemented from 1980 up to now, through multi stages of completion along the field life. [22, 23]

3. Experimental Work

3. Method and Materials

For evaluate operations re-injection of produced water were selected five cores of Main pay layer from Zubair formation with different depths at Rumaila North R-25 (1,3) R-56 (5,2,3) and 40 liter from produce water to carry out compatibility taste [15-17]. Figure (1) is shown the apparatus waterflooding for core in Laboratory and Quality Control Department in Basra Oil Company. The compatibility experiment includes two main stages:

1- Measured petrophysics properties of core, pore volume, porosity and permeability in air before injection.
2- Measured permeability core for water produced injection before and after damage. It is includes the following operations:
    - Saturated cores in filtered produced water (removing the suspended materials by a 0.45µ filter) for 7 days.
    - Pumping (500 cm^3) from PW (with online filter) in core and measured the permeability every 100 cm^3. The initial permeability K_i represented the average of measured permeability for fourth and fifth hundred from PW injection.
    - Pumping (100-2500 cm^3) from PW (without online filter) in core and measured the permeability after each100 cc until the permeability value is fixed. This fixed permeability represents the final permeability K_f after damage.

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Fig. (1): Apparatus of waterflooding in core lab

4. Results and Discussion

4.1. Routine analysis stage

Tables (2) show the petrophysics properties (pore volume, porosity and permeability in air) before injection.

Table (2) Main petrophysics properties

No.	Sample code	Depth (m)	V_b Pore volume (cc)	Ø (%) before saturation	K_{air} (md) before saturation
1	R-56(5)	3177.6	14.58	24.0	1620.0
2	R-25(3)	3245.4	13.51	22.2	1320.0
3	R-25(1)	3245.7	12.7	20.8	874.4
4	R-56(2)	3156.2	11.86	21.2	212.9
5	R-56(3)	3156.3	11.78	21.2	197.3
average			12.9	21.9	

According to Tables (1) and (2), we can classify the permeability of samples to very high and Exceptional as shown in Table (3).

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Table (3) Classify the permeability of samples

Permeability Value (md)	Classification
R-56(5)	Exceptional
R-25(3)	
R-25(1)	Very high
R-56(2)	
R-56(3)	

4.2. Produce water injection stage (Damage stage)

Table (4) shows water injection volume, permeability for after and before PW injection and formation damage degree. Permeability and damage are calculated by equations (1) and (2) respectively.

Table (4) Samples permeability types for PWRI

Sample code	cumulative water injection (cc)	K_i (md)	K_f (md) after damage	Damage degree %
R-56(5)	2200	1462.6	426.4	71
R-25(3)	2200	805.7	361.7	55
R-25(1)	2500	567.7	193.1	66
R-56(2)	2000	191.9	49.3	74
R-56(3)	2000	119.7	30.3	75
average	2180			68.2

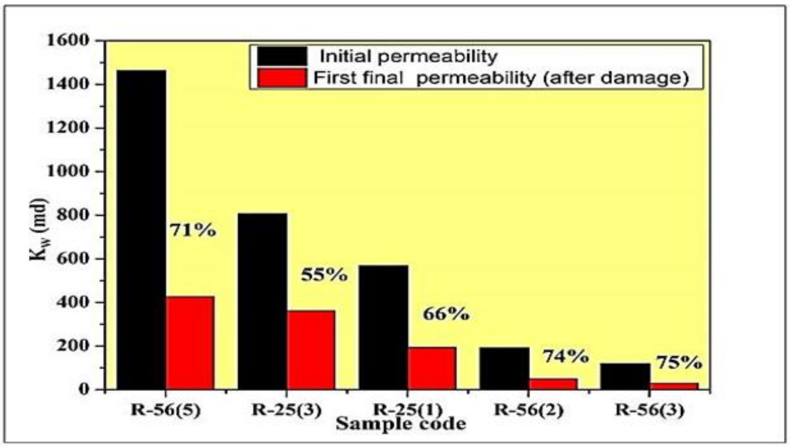

Fig. (2) Bar chart of permeability, before and after damage

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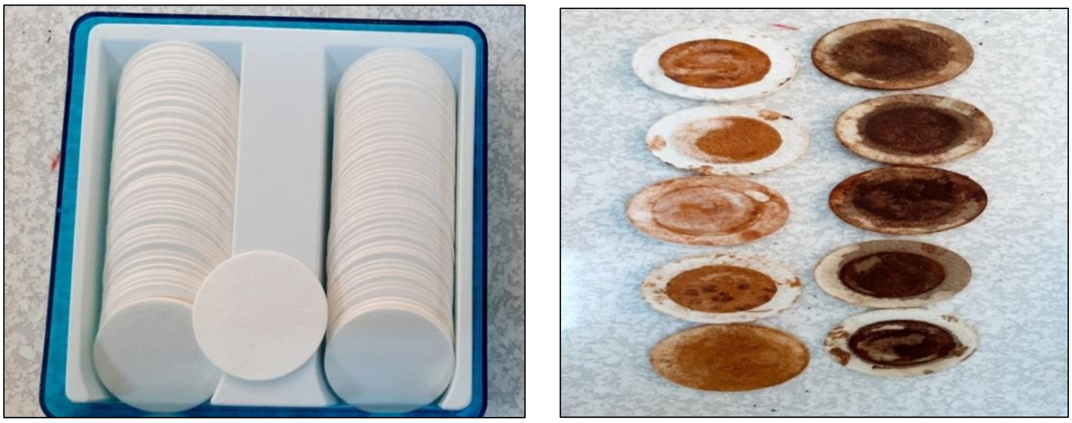
Figure (2) represents a bar chart of the permeability before and after damage in Table (4). From Figure (2), is we obtained important result:

1- The maximum damage degree is 71% and the minimum damage degree is 55% with average value 68.2%.

2- Although the core have a high permeability, directly inject the produced water without filtering, causing them significant damage.

3- We thought the main causes to impairment permeability are present high concentration from suspended solids as shown in Figure (3). Figure (3b) shows precipitation of suspended solids on filter during measured permeability for with online filter.



(a) (b)

Fig. (3): Watman filter (0.45 µm pore size) before (a) and after (b) injection

4- Also, we thought the main caused for damage is suspended solids and not swelling of the clay, because the produced water is characterized by high salinity.

5- The increasing of cumulative water injection leads to increase of TSS/ TDS concentrations in porous formation [10]. We conclusion the injectivity of a well operated under matrix conditions is dominated by formation damage caused by impurities in the injection water [2-4].

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4.3. Mechanism and monitor damage

We observe that the produced water coming out of the core is colorless and does not contain suspended solids unlike what it was before the injection operations as shown in Figure (4). This is mean that most of suspended solids, sediment and heavy metals (especially iron) remain inside pore of core and the core became as natural rock filter.

(a) (b)

Fig. (4): Produce water from North Rumaila (a) before and (B) after injection

If we assume that the formation is single layer homogeneous with constant thickness and porosity , the water flows in it uniformly in all directions along the axis of the well, vertical and areal sweep efficiencies of water are 100%, the distribution of perforation are helically and full penetrated along of pay layer and the distribution of TSS/TDS in PW is homogenous, the damage is start from maximum degree near wellbore because of the velocity of produce water flow at perforations locations is great than velocity of move suspended solid and this will leads to a large deposition at its. Consequently, the damage will be gradually decreasing away from wellbore and the permeability start jump up as shown in Figure (5) [26].The damage zone is propagate symmetrical around axial wellbore injector and connect together formed roughly circular dish.

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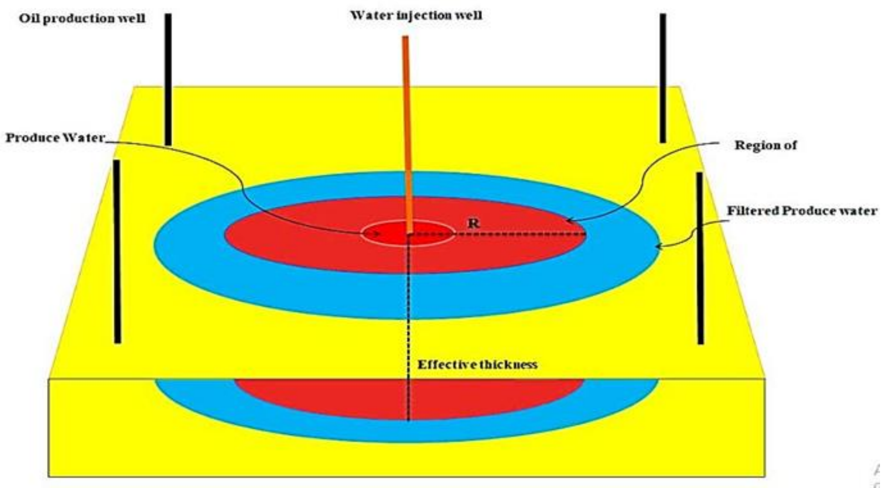

Fig. (5): Mechanism of produce water injection well patterns

For monitor damage, we assume that existence default wellbore injector in North- Rumaila oil field and full penetrated Main Pay formation with100 m net thickness of formation, 21.9% average porosity and 14000 bpd flow rate of water injection. By cumulative water injection -pore volume, together with the average water-injection rate, we can be predict the time required for the damage to reach maximum value (68.2%) and area of the formation around injection well as shown in Table (5) [37].

Table (5) The time duration damage as function to radius of area around injection well

Radial distance from the wellbore (m)	Time duration (year)
10	1
15	3
20	6
25	9
30	13

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4.4 Damage Treatment Strategy

Treatment strategy of damage formation caused by operation PWRI depending on degree of damage, damage zone area, duration injection, flow rate injection, TSS/ TDS concentration, characterize of formation and pattern injection. We can put treatment strategy as following [1, 27-29]:

1- Washing of formation by clean water
2- Using acidizing treatment.
3- Water injection under fracture.

5. Conclusion

1. Using produce water as injected water directly under matrix conditions in the Zubair formation in the northern Rumaila field causes reduction 68% from original permeability formation.
2. The damage is start from maximum degree near wellbore and gradually decreasing away from injection well and the permeability start jump up. The damage zone is propagate symmetrical around axial wellbore injector and connect together formed roughly circular dish.
3. The main cause of damage is suspended solid and dissolved solid.
4. Based on these results, direct injection of produced water into Zubair formation without surface treatments or washing of formation or acidizing treatment or injection under fracture conditions causes formation damage and increases with time.

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