Analysis of Reinjection Water to Improve Water-flooding Effect for Low-permeability Sandstone Reservoirs

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Abstract. Years of oilfield development practice indicates that the quality of injected water plays an important role in the water-injection process to improve the development effect. The low-permeability reservoirs have low yields and strict requirements on water quality indicators, and it is urgent to study the process of oilfield produced water treatment. The damage source and mechanism of re-injection water was discussed, and the compatibility between the reinjection water and the formation of water was analyzed and evaluated. The treatment process of water reinjection was studied, and the recommended indexes on injection water quality for low-permeability reservoirs for water-flooding development was given in this paper that provides a theoretical basis for the research of oilfield water-flooding development and injection water quality indicators for the future.

1. Introduction

Waterflooding development is widely used in the development of the low-permeability reservoir in the Ordos basin. It compensates formation energy by injecting formation water, to drive the water to displace oil in pore and throat improving the oil recovery of tight oil. However, years of oilfield development practice indicates that the quality of injected water plays an important role in the water-injection process and effect. The low-permeability reservoirs have low yields and strict requirements on water quality indicators, and it is urgent to study the process of oilfield produced water treatment. The injected water has good compatibility with reservoir rocks and its fluids, which is the pre-requisite for ‘filling enough water and filling fine water’ in the water-flooding. The degree of compatibility directly affects the water absorption capacity of the injection well (Jiang et al.,2003; Huang et al.,2000; Morrow N et al.,2011; Li et al.,2005). Due to the poor physical properties and low productivity of low-permeability reservoirs, the incompatibility of injected water and reservoirs property in the process of water-injection development is likely to cause reservoir damage, and these injuries are often irreversible, causing a rapid decline in production capacity, resulting in shortened development cycles of oilfields. Ultimately, the recovery rate is reduced, which affects the economic and effective development of the reservoir. The compatibility of the injected water was studied by static test evaluation method and analysis on the characteristics of high-content iron in the oil sample from reinjection water (Wang et al.,2010). Analysis of compatibility of injected water and producing layer in water-injection by microscope and scanning electron microscope (Zhao,2013); the evolution model of clay minerals and their rock sensitivity in water flooding development and the hydrophilicity of rock wettability can further
improve the water flooding efficiency of reservoirs; and stress sensitivity on the effective development of low-permeability reservoirs has been discussed (Gao et al., 2014; Peng et al., 2006).

This paper tries to analyze the mechanism of reinjecting water damage to the stratum and put forward the evaluating index for injection water and the decision-making ideas of the compatible water injecting water, finally, the steps of reinjection water treatment process has been established.

2. The source and mechanism of rejection of water
To restore formation capacity requires a certain period by water injection in the oilfield, and it is a long-term behavior. With the damage around the wellbore in the conventional drilling, the injection water is easily formed deep damage, and its damage can be accumulated in the stratum. For example, in the case of hydraulic fracturing; generally, the damage depth is not up to 2 meters. Once formed, the damage is difficult to remove, so we think the reservoir protection is the first thing to prevent kinds of damages during the water injection process, and the damage caused by the injected water to the reservoir is mainly showed as followings in figure 1.

![Figure 1. Reinjection water sources in oil filed water injection](image)

3. Compatibility with the formation water
3.1. Sample Collecting
The water samples from the X-field in the Ordos Basin were collected with 50 liters of the formation water from the Chang 6 reservoir; and 100 liters of the injected water.

3.2. Method of water quality analysis
Cationic concentration has been determined using ICP cation chromatograph, and oil content and suspended solids have been tested according to SY/T5329-94 "Recommended index and analysis method for water quality of clastic reservoirs" from CNPC, and pH value has been gained using PB-10 acidity meter. Based on the data above, with a method for judging the chemical type of water system, the type of mineralization has been measured finally. When the water sample of X-field is taken, it is stored in a sealed container. When the water sample is taken, it is found that the water samples have turned into a turbid white liquid. After standing for 2 hours in the open air, the solution turned yellow, and a yellow precipitate appears. The results show that the yellow substance is an iron compound and it can obtain that the total iron content of Chang 6 formation is 56.19 mg·L⁻¹, the Fe²⁺ existed ubiquitously in original formation water, after contact with air, it is oxidized to Fe³⁺, and then hydrolyzed to form Fe(OH)₃ precipitation in yellow color in figure 2.
4. The treatment process of water reinjection

4.1. Sample Collecting

Based on the data collected in this work, for the reservoir with ultra-low permeability and the current level of water treatment technology and economic feasibility, and this standard is used in this work, and it is as follows:

(1) suspended matter content <0.5mg / L;
(2) oil content <3mg / L;
(3) The median particle size of the suspended matter is <0.5μm.

4.2. Ultra-filtrations for Treating Reinjection Water

The process of ultra-filtration for treating reinjection water has been adapting in injecting water of water-flooding development for low-permeability sandstone reservoirs and process flow diagram as shown in Figure 2. The details are as follows:

The oily waste-water firstly enters the grease trap, and the oil spill mostly removes. The gas dissolved in the air flotation tank that micro-bubbles make impurities in the medium bubbled to the surface with dosing, which can remove more than 90% of petroleum substances and most of the solid suspended matter. And then the effluent from the flotation tank enters the dual filter where a small number of petroleum substances and a small amount of suspended matter remaining removes. The effluent enters the fine filter, the petroleum substances and suspended matter will be further removed in the fine filter, where the effluent can satisfy the water standard in the ultrafiltration inlet; the fine filter effluent enters the ultrafiltration membrane system for treatment. The filtration precision of ultrafiltration membrane reaches nanometer level, which can have a very good interception effect on the tiny suspended solids, bacteria and petroleum substances in oily waste-water. The effluent of the ultrafiltration system can directly meet the processing requirements, and then the treated water can be re-injected into the formation by adding suitable antiprecipitant.

Figure 2. The change of ion concentration in the injecting water as time goes
4.3. Analysis of the Removal
During the test, the average content of hydrocarbon in the incoming water is 198.5mg/L by monitoring, the concentration of hydrocarbon in the oil-separating tank is 125.4mg/l, and the content of hydrocarbon in the air flotation is 12.05mg/l. The content of effluent in the dual filter is 1.12 mg/l, the concentration of hydrocarbon in fine filtration is not detected, and the concentration of hydrocarbon in ultrafiltration effluent is also undetected.

The removal rate of the oil-separating tank for suspended solids is 15.7% for suspension and 70%, 79.6%, 46.1% respectively in the devices of air flotation, dual filter, fine filter. And it is 100% in the devices of ultra-filtration, and the total removal rate of suspended solids by the whole system is 100%.

5. Conclusion
Waterflooding development is widely used in the development of a low-permeability reservoir in the Ordos basin. Years of oilfield development practice indicates that the quality of injected water plays an important role in the water-injection process to improve the development effect. The low-permeability reservoirs have low yields and strict requirements on water quality indicators, and it is urgent to study the process of oilfield produced water treatment. The damage source on the rejection water includes solid suspension, dissolved gases, mineralization, lubricating grease, bacteria and sensitivity, and its damage mechanism is also discussed in this paper. The presence of suspended solids and a reaction product or precipitation of mineralization, bacteria and lubricating grease can block the pore throat resulting in the permeability reduction. And the results show that the degree of speed-sensitive damage is moderate, the level of salt sensitivity damage is moderate, the acid sensitivity is weak; and the water sensitivity, salt sensitivity, and stress sensitivity is strong respectively. The compatibility between the reinjection water and the formation of water has been evaluated. If the compatibility is not good, which will cause precipitation or scale, and the treatment process of water reinjection is studied. Only the water treated to gain good compatibility fits the recommended indexes for low-permeability reservoirs can be used for water-flooding development.

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