

# Research on Reservoir Damage Mechanism in Oilfield Waterflood Development

Ying Sun

School of Xi'an Shiyou University, Shaanxi 710000, China

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**Abstract:** Oilfield waterflood development is an important means to improve oil recovery, maintain formation pressure and increase production. Although water injection technology has been widely used, the reservoir damage in the process of water injection is still one of the key factors affecting the production efficiency and sustainable development of oil fields. Therefore, it is very important to understand the mechanism of reservoir damage for the analysis of underinjection. This paper aims to investigate the main mechanism of reservoir damage in oilfield waterflood development, analyze its causes and influencing factors, and discuss the technical measures to solve reservoir damage, so as to provide theoretical basis for oilfield waterflood development.

**Keywords:** Waterflood development; Reservoir damage; Suspended particles; Oilfield development.

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## 1. Introduction

In the process of oilfield waterflood development, water quality, water injection method and the interaction between water and reservoir rocks and fluids will cause different degrees of damage to the reservoir. Reservoir damage will not only reduce water injection efficiency, but also affect oil and gas recovery, and even lead to the failure of water injection Wells. Therefore, studying the mechanism, prevention and treatment of reservoir damage has become an urgent problem to be solved in oilfield waterflood development.

At the same time, excessive water injection pressure will also lead to reservoir damage. Reservoir damage may be either a potential damage factor of the reservoir itself or caused by improper operation during waterflood development[1]. It is very important to understand the mechanism of reservoir damage, especially to analyze the cause of water well underinjection, for improving the operation of water injection and improving the efficiency of oilfield development.

## 2. International Research Progress of Reservoir Damage Mechanism

Internationally, the study of reservoir damage mechanism began in the 1960s. In 1965, Bason summarized and analyzed field experiments and concluded that reservoir damage was mainly caused by capillary phenomenon, solid particle invasion, scale formation and damage factors of the reservoir itself[2]. In 1972, Barkman and Davidson summarized the damage mechanism of Wells, including four basic types: hole plugging, hole filling, particle invasion and hole narrowing. In 1979, Donaldson conducted experiments on suspended matter passing through porous media and found the correlation between particle migration in pores and linear velocity[3]. In 1979, Todd et al. conducted the suspended matter particle plugging experiment. They used the comparison of control variables and concluded that the permeability would also be affected by the generated inorganic solid phase[4]. In 1984, Todd et al. found that the size of the average pore throat is significantly related to the

damage degree of the core, and the core is most susceptible to damage by 0-3 $\mu$ m particles, and the damage of the core will decrease with the increase of the particle size[5].

In 1985, Basan studied the mechanism of reservoir damage. Based on qualitative and empirical results, the research results showed that the main damage factors were suspended particle invasion and potential damage of the reservoir itself. Moreover, they also summarized the characteristics of damage, namely, porosity around the borehole, chemical precipitation, lattice expansion, particle migration, dispersion and migration. Prior to this, there was no literature to study the reservoir damage factors from the nature of the reservoir itself[6].

In 2000, Joannathan's study found the damage caused by bacteria to reservoirs and the damage caused by reservoirs themselves[7]. In 2002, Brant proposed the concept of thermal injury[8]. In 2008, Ayman et al. believed that iron ions would react with viscoelastic surfactants to produce gels, which would lead to blockage of seepage channels[9]. In 2014, Wojtanowicz et al built a model to predict the degree of damage to formation permeability caused by emulsified oil in injected water[10]. In 2016, Kalantarias et al. built an analytical model of the relationship between time and water absorption index of low permeability reservoir[11]. In 2018, Borazjani et al. constructed a two-phase axisymmetric flow semi-analytic model to analyze the tightness of the relationship between reservoir permeability, injected water salinity and suspended particles, which can describe the changes of skin factors during water injection. It can also explain the correlation between well water absorption capacity and kaolinite content in clay minerals, relative permeability, crude oil viscosity, and injection rate[12].

Foreign research on reservoir damage mechanism is more focused on mechanism research and prediction. By establishing physical and mathematical models and combining database for prediction and diagnosis, it requires less on-site data, relies less on it, and can quickly determine the factors causing reservoir damage and take effective countermeasures[1].

### 3. Domestic Research Progress of Reservoir Damage Mechanism

The study of reservoir damage in China started relatively late, and the study of reservoir damage mechanism and oil and gas reservoir protection technology began in China in 1980[1]. During this period, I also learned from foreign advanced experience and began to study the application of prediction model in reservoir damage. While achieving remarkable results in practical technology, the level of simulation research also reached the international leading level at that time. Since then, China's oil and gas formation damage mechanism and protection technology have been popularized and applied in the oil field, and combined with the actual geological conditions of our country, gradually formed their own technical barriers and advantages.

With the development of science and technology and the promotion of multi-disciplines, many new methods have begun to be applied in the study of reservoir damage mechanism, mainly including CT scanning technology, nuclear magnetic resonance scanning imaging technology, scanning electron microscopy technology, energy spectrum detection technology and other means. These techniques can be used to study the migration of solid particles in the formation pores, the motion state of fluid in the formation and the depth of invasion. It can also calculate and measure reservoir sensitivity and damage degree through indoor five-sensitivity experiment and injected liquid damage experiment, and adjust the development plan accordingly to better protect the reservoir.

### 4. Main Types of Reservoir Damage

Reservoir damage refers to the phenomenon that water interacts with reservoir rocks and fluids during water injection, resulting in adverse changes in the physical and chemical properties of reservoirs[13]. According to different mechanism of action, reservoir damage mainly includes the following types:

#### 4.1. Physical Damage

The physical damage is due to the change of the pore structure and permeability of the reservoir when the water flow passes through the reservoir during the water injection process, which leads to the decline of the reservoir storage and flow performance. The main physical damage includes speed sensitive damage and reservoir damage caused by particle migration and deposition. In the process of water injection, suspended matter and solid particles in water may be deposited in the reservoir, blocking the pore channel and reducing the permeability of the reservoir.

#### 4.2. Chemical Damage

Chemical damage refers to the change of water quality of injection or the chemical reaction caused by the interaction between injection water and reservoir rocks or fluids, resulting in structural changes of reservoir rocks or fluids. Common chemical injuries include: acid-sensitive damage, water-sensitive damage and scaling damage[14]; Acid sensitive damage means that during the water injection process, the chemical composition of the water (such as acids, bases, etc.) may react with minerals in the reservoir, resulting in mineral dissolution, precipitation, or the formation of harmful substances. Water sensitive damage means that some

reservoir minerals may absorb water and expand during water injection, which changes the pore structure of the reservoir and further reduces the permeability. Scale damage refers to the fact that injected water in some oil fields may react with dissolved minerals in the reservoir, resulting in mineral precipitation and the formation of sediments that clog pores.

#### 4.3. Microbial damage

Microbial damage refers to the interaction between microbial community in water and reservoir during water injection, resulting in changes in reservoir rock or fluid properties[15]. Common microbial injuries include: microbial growth and reproduction and microbial blockage; Microbial growth and reproduction refers to the possible existence of microorganisms in injected water, which grow and reproduce in the reservoir and produce metabolites, such as acids and gases, which may lead to the dissolution, corrosion or formation of precipitation of reservoir minerals. Microbial plugging means that the proliferation of microorganisms may form biofilms, block pores, and reduce reservoir permeability and water injection efficiency.

### 5. Influencing Factors of Reservoir Damage

The extent and type of reservoir damage is affected by a variety of factors, including the following:

#### 5.1. Quality of injected water

The injected water quality plays a decisive role in reservoir damage. Suspended matter, dissolved gas, mineral composition and oil content in water may cause damage to the reservoir in different degrees. For example, when the dissolved oxygen content of water is high, it may lead to the oxidation and dissolution of minerals, forming a precipitate; Microorganisms in the water may also trigger biochemical reactions, leading to reservoir contamination[16].

#### 5.2. Reservoir characteristics

Reservoir properties such as lithology, porosity, permeability and mineral composition of rock will also affect the degree of reservoir damage. For example, highly permeable reservoirs are vulnerable to physical damage, while low permeable reservoirs may crack due to excessive water injection pressure during water injection, resulting in more serious reservoir damage.

#### 5.3. Injection Mode

Water injection methods include injection pressure, flow rate, water injection and other factors. High pressure water injection or high flow water injection may lead to fracture of reservoir rock and increase the risk of reservoir damage. However, the lower water injection velocity may not be able to effectively displace the crude oil in the reservoir, resulting in poor water injection effect[17].

### 6. Measures to Solve Reservoir Damage

In the process of oilfield waterflooding, the causes of reservoir damage are usually closely related to the quality of injected water, the invasion of suspended particles, scale formation and the potential factors of the reservoir itself. In

order to effectively deal with these problems, the following prevention and control measures are summarized:

### 6.1. Optimize injected water quality

Ensure that the injected water quality meets the standards to reduce the impact of suspended particles and harmful substances in the water on the reservoir. In the process of oilfield water injection, the injected water quality should be strictly controlled to ensure that the water quality meets the requirements of reservoir and development. It can use treated sewage or recycled water to reduce the content of suspended matter and microorganisms in the water; Add preservatives, fungicides and other chemical additives to reduce the damage caused by microorganisms; Water quality is checked regularly through water quality monitoring equipment to ensure that it meets requirements.

### 6.2. Reservoir modification technology

In view of the heterogeneity and uneven permeability of the reservoir, reservoir modification technology can effectively reduce the damage of the reservoir. For example, the use of acidification, fracturing and other technologies to improve the permeability of the reservoir, promote the uniform distribution of water flow, reduce the damage caused by water injection.

### 6.3. Fine water injection management

Refined water injection management can reduce reservoir damage caused by improper water injection. Stratified water injection can be used to ensure the uniform distribution of water injection; Control water injection pressure reasonably to avoid reservoir damage caused by excessive water injection pressure. The potential damage to reservoir is reduced by optimizing waterflood operation measures. Optimize the time and flow rate of water injection, and control water injection pressure according to reservoir characteristics to ensure even water distribution and avoid local overpressure damage; Regular monitoring of water injection well flow, pressure and other parameters, timely adjustment of water injection scheme.

### 6.4. Reservoir protection technology

A variety of reservoir protection technologies, such as chemical inhibitors, filter cake technology, low-damage water injection technology, are used to reduce the damage to the reservoir and improve the effect of water injection.

## 7. Conclusion

To sum up, reservoir damage mechanism in oilfield waterflood development is a complicated and multi-factor interaction process. Research at home and abroad shows that reservoir damage is mainly caused by injected water quality, suspended particles invasion, scale formation and potential factors of the reservoir itself. In order to improve the efficiency of water injection and oilfield development and solve the problem of reservoir damage, researchers continue to deeply study the mechanism and influencing factors of reservoir damage, constantly explore new methods and technologies, and take effective technical measures. At the same time, the accurate prediction model is established to effectively improve the development effect of oil field water injection, and promote the efficient development of oil field and the improvement of economic benefits. In the future, with

the continuous progress of technology, the oilfield water injection development will develop in the direction of more accurate, efficient and environmental protection, providing guarantee for the sustainable development of the oilfield.

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