TEO Plc.
TECHNOLOGY ENHANCED OIL Plc.

Description of selected technologies | Nanoparticles

Increasing waterflood oil recovery in ClearFork Formation - Brooklaw Field

TEO is in the vanguard of companies applying new EOR technologies to increase oil recovery during waterflooding. Our plan is to evaluate the use of nanoparticles to enhance oil displacement in order to reach additional reserves and improve oil recovery, increasing the value of the asset.

How does conventional waterflooding work?

Conventional waterflooding is the injection of water into an oil reservoir in an effort to increase production, reserves and oil recovery, when the natural energy of the reservoir has been drained by primary production. The injection of water is known as secondary recovery and it replaces the "voidage" left by previously produced oil, increasing the reservoir pressure and displacing remaining oil from pore spaces.

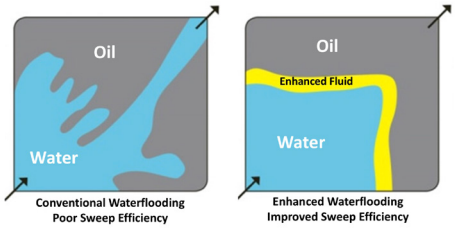
Decades of waterflooding applications in oilfields around the world have exposed the principle limitations of conventional methods to obtain a greater oil recovery. Conventional waterflooding can leave a high portion of the original oil in place (OOIP) as the injection water often has poor sweep efficiency and bypasses oil zones for various reasons including capillary forces, permeability contrast, differences in fluids viscosity, amongst others.

EOR for an enhanced waterflooding process

Enhanced waterflooding uses chemical water-based methods to increase oil recovery by mobilizing additional oil through improved microscopic and macroscopic displacement efficiency.

This displacement efficiency improvement can be achieved by several mechanisms:

- Increasing the water viscosity to improve the mobility ratio
- Decreasing the interfacial tension between oil and water to form oil-water emulsions
- Decreasing adsorption to lower the amount of chemicals used
- Wettability alteration for a more favorable displacement
- Increasing the viscoelasticity of the injected fluid to extract oil from dead end pores



Nanoparticles on EOR

Nanoparticles have gained the attention of the EOR community, as they have a large surface-to-area volume with high chemical reactivity. This means fewer nanoparticles are required to achieve an equivalent function of an EOR agent such as a surfactant or polymer.

Nanoparticles are solids of an average size smaller than 100nm and can be used to increase the efficiency of chemicals in reservoirs in specific location/conditions. This on demand increase of chemicals can be enhanced by formation water salinity and specific concentration of nano-particles. Nanoparticles can also be engineered to swell and block large channels to force flow through narrower paths and improve sweep efficiency.

Due to their small size, large volume surface area and high silica composition, nanoparticles are environmentally friendly and less expensive than chemicals that are often required in high concentrations and result in costly water treatments.

Chemical water-based methods include the use of surfactants, polymers, alkaline, or a combination of these, and more recently the use of nanoparticles.

SURFACTANT → Reduces capillary forces that drop oil in the reservoir by decreasing the interfacial tension between oil and water

POLYMER → Improve mobility ratio and sweep efficiency by increasing water viscosity

ALKALI → In situ surfactant generation, reducing capillary forces by decreasing the interfacial tension

NANOPARTICLES → Nanoparticles can be used to generate the same effect as Surfactants and Polymers and also to enhance their action

Latest advances in EOR by using nanoparticles

Silica nanoparticles have been successfully tested in laboratory core floods to improve oil recovery in carbonates and sandstones. Nanoparticles are excellent candidates for EOR as it has been proved they can:

- Modify the wettability of the rock surface
- Modify the interfacial tension between oil and water
- Form oil-water emulsions
- Change the viscosity of both oil and water
- Divert water flow to less permeable zones
- Exhibit viscoelastic behavior (similar to polymers)
- Enhance surfactants and polymers action

With the help of a London based team of specialists, TEO has identified the most likely combinations of surfactant and nanoparticles which may be efficient on carbonates, and is about to test them on core samples from the Brooklaw Field.

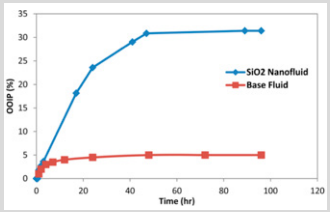
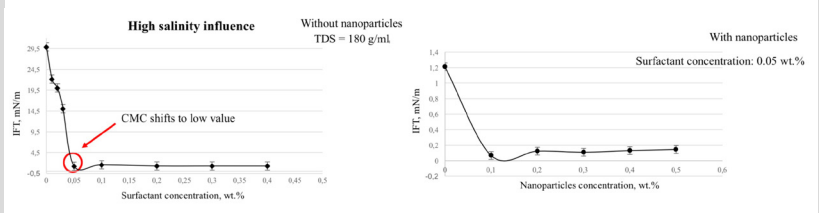
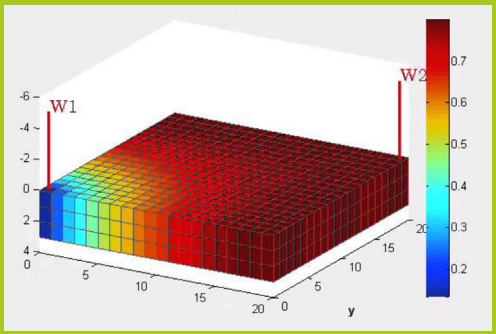


Fig. A. Percentage of OOIP (original oil in place) recovered during spontaneous imbibition using a base significantly increases oil recovery. Figure taken from Moghaddam et al. (2015).





State-of-the-art simulations to predict the benefit of using next generation waterflooding

TEO is currently working with the Skolkovo Institute of Science & Technology (Skoltech) in Russia and Cervart, which has developed a new machine-learning based simulator for reservoir modeling that has been successfully used in carbonate reservoirs similar to the ClearFork Formation.

The outputs from these simulations, using the results from core samples testing, will provide TEO with a more robust waterflooding scheme, including the influence of nanoparticles, that most reservoir simulators do not take into consideration.

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