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Microbial EOR makes gains

New technology that introduces functional microbes along with nutrients into the reservoir shows promise as an MEOR solution.

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As oil prices have risen and remain high, EOR has become an increasingly important topic among oilfield operators. EOR technology targets the tough-to-get oil in conventional plays, typically the 55% to 80% of oil left *in situ* after primary and secondary recovery have been executed.

EOR has recently become a hot topic for many reasons, the biggest being maturing wells and high crude prices that allow the technology to pay out. Much EOR technology tends to be expensive and/or energy-intensive. Microbial EOR (MEOR), a treatment that uses native microbes to recover oil, is an affordable, low-footprint option in fields of moderate temperature, salinity, and permeability. Especially in sandstone and consolidated sandstone formations, this technology is simpler to implement and can compete with the performance of chemical EOR or can even be combined with it to increase its effectiveness.

Microbial treatment takes advantage of oil-releasing qualities found naturally in certain microbe species native to the oil reservoir environment. MEOR can address flow conformance or residual oil saturation. Flow conformance is improved through a bioplugging mechanism in which a microbe produces biopolymers that block preferred channels and force water into new locations of the formation, improving sweep efficiency. The oil release mechanism takes advantage of the properties of indigenous microbes to release biosurfactants that reduce the surface energy holding the oil to the rock. In most cases, MEOR consists of enhancing the activities of these special microbes through the periodic injection of tailored nutrients downhole.

MEOR is estimated to cost around US $10/bbl of produced incremental oil. The technology uses pre-existing waterflood equipment. The periodic treatment is normally brought in on a tank truck and piped to the injector manifold for pumping. After the treatment is pumped, the pipes are disconnected and the truck drives away. Compare this method to alkali surfactant polymer chemical EOR, which requires a significant investment in infrastructure, from mixing tanks to additional pumps to treater tanks for hard-to-break emulsions. Above ground, MEOR has no footprint. Below ground, once feedings are stopped, the ecology of the reservoir will return to its natural state, and the effects caused by the microbe treatment dissipate over time. MEOR can be applied to high-water-cut wells in the later stages of secondary production or at the beginning of a waterflood treatment to increase production. It may also be used in conjunction with other EOR technologies. MEOR is a reversible process.

MEOR and inoculation

DuPont began to research MEOR eight years ago, and in 2012 the company's Matrx EOR Technology was introduced. Over the years, the research and logistics

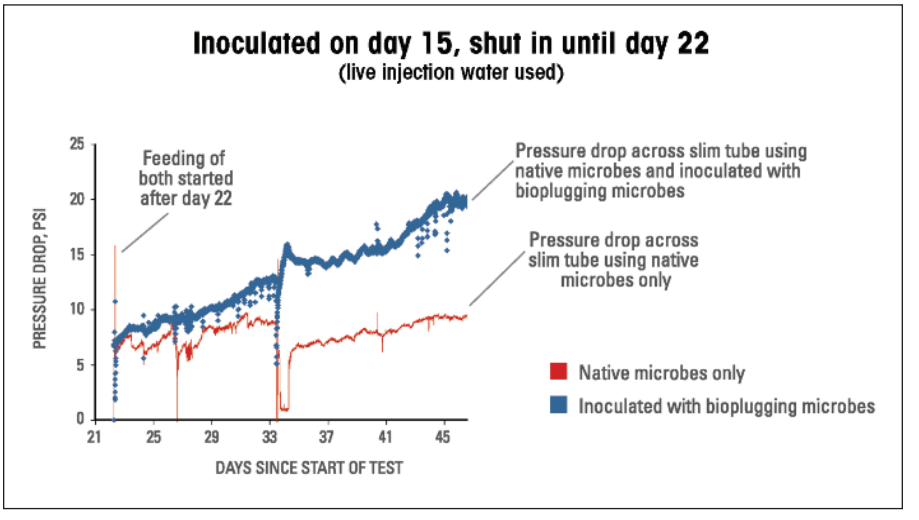

FIGURE 1. A slim-tube pressure-drop test demonstrating bioplugging shows the contrast between using live injection water with native microbes only compared to inoculated live injection water. (Images courtesy of DuPont Sustainable Solutions)

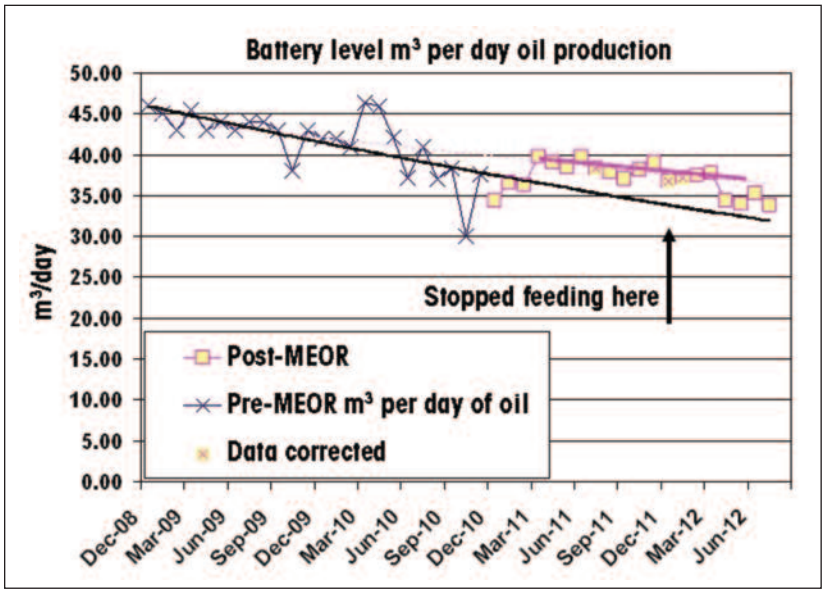

FIGURE 2. A 15% to 20% increase in production rate was demonstrated for affected producers with a corresponding decrease in water cut after the MEOR technology was deployed.

team became convinced that inoculation, in which a fermented batch of the functional microbe is injected in large volumes as a broth prior to nutrient injection, is critical to success. The method of putting only nutrients down a well is not enough for consistent results, and lab tests support this finding, as is highlighted in Figure 1. The figure shows a pair of identical slim tubes treated in an identical manner using "live" injection water to provide the background of organisms present in the well. One slim tube, however, was inoculated with the preferred microbe while the other was not. Both were fed nutrients. Only the inoculated slim tube presented the desired bioplugging mechanism.

Once the reservoir is inoculated, the microbes are fed a customized aqueous nutrient solution that is pumped downhole periodically. DuPont relies on a proprietary injection process protocol to ensure that nutrient effects are propagated far beyond the wellbore to prevent wellbore fouling and to ensure that the inoculated microbes deep within the reservoir are fed. Inoculation is repeated one or two times per year. Nutrients are fed more frequently, generally on a monthly basis. The effects of MEOR can take anywhere from one to four months to show up since the effects are deep in the reservoir. Like other EOR treatments, the microbes need time to propagate into the reservoirs and perform the function, factoring in biological response time. This can be seen in data from a very successful field trial carried out from 2010 to 2011 and presented in Figure 2.

Three months after the battery was inoculated and given monthly nutrient feedings, a clear and sustained jump is observed in the figure. The elevated production also lasted months beyond the last feeding.

These results are from a partial treatment of a field in Alberta, Canada, in which three out of 10 injectors in this field served by this single battery were treated. The increased production shown in Figure 2 represents a 15% to 20% increase in production rate for the affected producers with a corresponding decrease in water cut after the MEOR technologies were deployed. Production rates rose due to an increase in sweep efficiency using the bioplugging mechanism. Measuring the increase in injection pressure at a constant injection flow was a challenge but served as a key indicator that the technology was able to develop significant and sustainable bioplugging of the reservoir as it was designed to do, significantly improving flow conformance. These results were achieved with a much smaller environmental and capital footprint than other EOR technologies.

Overcoming biases

MEOR providers still fight to overcome biases in the oil and gas industry. Sustaining and encouraging microbial life in wells sounds counterintuitive to many reservoir engineers and operators. Certain microbe classes such as sulfate-reducing bacteria (SRB) can be particularly damaging, contributing to corrosion of ferrous metal surfaces and oil recovery equipment as well as souring and plugging. However, the Matrx technology relies on nitrate-reducing bacteria, which are generally benign. Data show that the technology may actually inhibit the growth of harmful SRB.

Future growth

Matrx MEOR Technology is steeped in the company's foundational experience with industrial biosciences and combines the company's expertise in chemical and biosciences with its growing presence in the upstream oil and gas sector. The company is now looking for partners in the US market to deploy the technology. DuPont continues to evaluate other ways in which microbiology can be used in various upstream processes or combined with other EOR methods like CO_2 flooding. DSP