Nanoparticles helping to recover more oil

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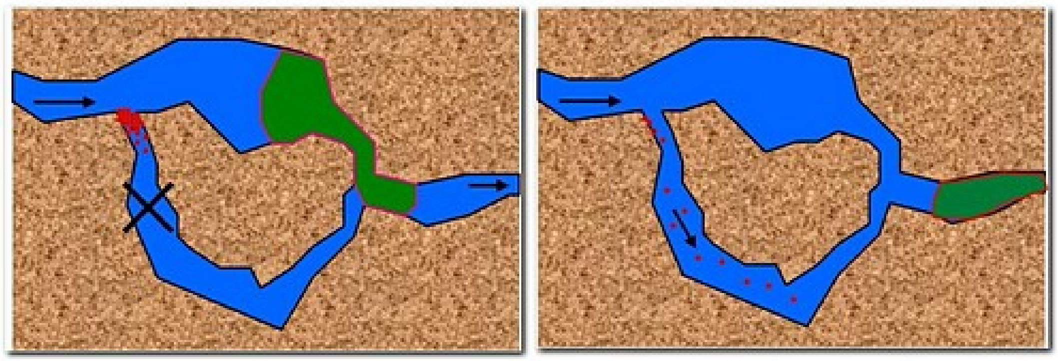

Left: The density gradient between particles and water slows the particles' movement through the winding passages within the rock. The particles accumulate and consolidate at bottleneck points to block the rock pores. The pressure builds in adjacent pores, forcing out the oil (shown in green). Right: Once the oil is freed, the surrounding pressure drops. The blockages gradually dissolve and the polymer particles commence flowing with the water. Credit: CIPR

When petroleum companies abandon an oil well, more than half the reservoir's oil is usually left behind as too difficult to recover. Now, however, much of the residual oil can be recovered with the help of nanoparticles and a simple law of physics.

Oil to be recovered is confined in tiny pores within rock, often sandstone. Often the natural pressure in a reservoir is so high that the oil flows upwards when drilling reaches the rocks containing the oil.

Less oil without water

In order to maintain the pressure within a reservoir, oil companies have learned to displace the produced oil by injecting water. This water forces out the oil located in areas near the injection point. The actual injection point may be hundreds or even thousands of metres away from the production well.

Eventually, however, water injection loses its effect. Once the oil from all the easily reached pores has been recovered, water begins emerging from the production well instead of oil, at which point the petroleum engineers have had little choice but to shut down the well.

The petroleum industry and research community have been working for decades on various solutions to increase recovery rates. One group of researchers at the Centre for Integrated Petroleum Research (CIPR) in Bergen, collaborating with researchers in China, has developed a new method for recovering more oil from wells – and not just more, far more.

The Chinese scientists had already succeeded in recovering a sensational 15 per cent of the residual oil in their test reservoir when they formed a collaboration with the CIPR researchers to find out what had actually taken place down in the reservoir. Now the Norwegian partner in the collaboration has succeeded in recovering up to 50 per cent of the oil remaining in North Sea rock samples.

To achieve these high recovery rates, the researchers make use of a simple physical phenomenon depicted in the figure above.

Nano-scale traffic jams

Water in an oil reservoir flows much like the water in a river, accelerating in narrow stretches and slowing where the path widens.

When water is pumped into a reservoir, the pressure difference forces the water away from the injection well and towards the production well through the tiny rock pores. These pores are all interconnected by very narrow tunnel-like passages, and the water accelerates as it squeezes its way through these.

The new method is based on infusing the injection water with particles that are considerably smaller than the tunnel diameters. When the particle-enhanced water reaches a tunnel opening, it will accelerate faster than the particles, leaving the particles behind to accumulate and plug the tunnel entrance, ultimately sealing the tunnel.

This forces the following water to take other paths through the rock's pores and passages – and in some of these there is oil, which is forced out with the water flow. The result is more oil extracted from the production well and higher profits for the petroleum companies.

Elastic nanoparticles

The particles that are used are typically 100 nanometres in diameter, or 100 times smaller than the 10-micron-wide tunnels.

The Bergen and Beijing researchers have tested a variety of particle sizes and types to find those best suited for plugging the rock pores, which turned out to be elastic nanoparticles made of polymer threads that retract into coils. The particles are made from commercial polyacrylamide such as that used in water treatment plants. Nanoparticles in solid form such as silica were less effective.

China first with field studies

The idea for this method of oil recovery came from the two Chinese researchers Bo Peng and Ming yuan Li who completed their doctorates in Bergen 10 and 20 years ago, respectively. The University of Bergen and China University of Petroleum in Beijing have been cooperating for over a decade on petroleum research, and this laid the foundation for collaboration on understanding and refining the particle method.

Field studies in China not only yielded more oil, but also demonstrated that the nanoparticles indeed formed plugs that subsequently dissolved during the water injection process. Nanoparticles were found in the production well 500 metres away.

"The Chinese were the first to use these particles in field studies," says Arne Skauge, Director of CIPR. "The studies showed that they work, but there were still many unanswered questions about how and why. At CIPR we began to categorise the particles' size, variation in size, and structure."

At first it was not known if the particles could be used in seawater, since the Chinese had done their trials with river water and onshore oilfields. Trials in Bergen using rock samples from the North Sea showed that the nanoparticles also work in seawater and help to recover an average of 20?30 per cent, and up to 50 per cent, more residual oil.

Centre of Excellence of great benefit to society

The Centre for Integrated Petroleum Research (CIPR) is the only institution for petroleum research under the Centres of Excellence (SFF) scheme. CIPR is now supplementing its expertise on oil reservoirs with nanotechnology know-how in seeking ways to recover residual oil.

Success could have far-reaching impacts. The state-owned petroleum company, Statoil, is seeking to increase current recovery rates, which range from under 50 per cent, to roughly 60 per cent.

"We hope this new method can help to raise recovery rates to 60?65 per cent," says Mr Skauge.

Looking to field test

Now the Bergen researchers want to test out the method large-scale.

"We'd like to try it in the North Sea and are in contact with Statoil, but we are certainly not the only ones hoping for a chance. We are competing with many promising methods for raising recovery rates," explains Mr Skauge. "That is why we may well test the method onshore in other regions, such as the Middle East. Several actors from there have contacted us after reading our published papers."

Still questions unanswered

In the meantime the researchers will be learning as much as they can about particles and pores.

"We are working hard to understand why the particles work well in some rock types and more marginally in others," says Kristine Spildo, project manager at CIPR. "This is critical for determining which North Sea fields are best suited to the method."

The research has received funding under the Research Council of Norway's Large-scale Programme for the Optimal Management of Petroleum Resources (PETROMAKS) and from Statoil, among others.

Provided by The Research Council of Norway