

OILFIELD TECHNOLOGY

EXPLORATION | DRILLING | PRODUCTION | JANUARY 2019

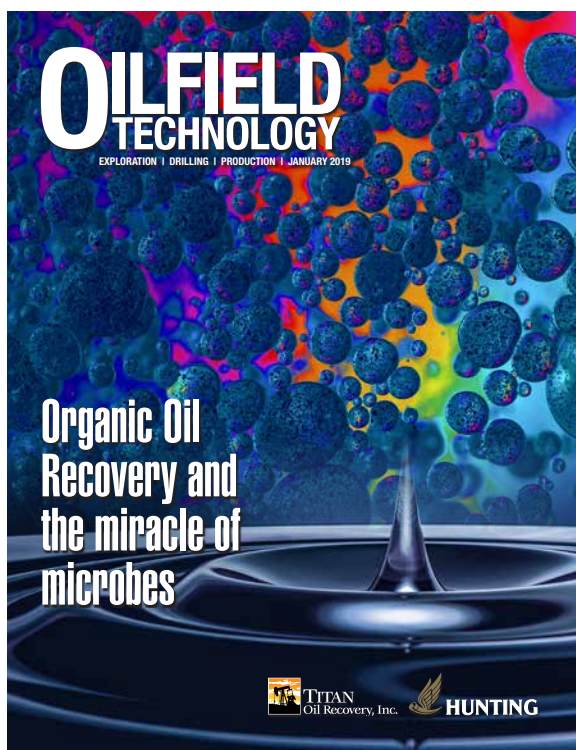
Organic Oil Recovery and the miracle of microbes



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Front cover:

Titan Oil Recovery is an oil service company specialising in enhanced oil recovery for offshore and onshore oilfields.

Titan's Organic Oil Recovery technology has been applied on four continents to 48 oilfields, is biodegradable and requires no capital expense.

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Sales and service options are located in the major oil centres of the world, comprising over 80 company owned facilities and a network of more than 60 licensed partners.



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An Organic Approach to Oil Recovery



Kenneth J. Gerbino and Dr. Colin Hill, Titan Oil Recovery, USA, explain how a new organic approach to oil recovery is providing benefits for operators.

Major problems that have faced the oil industry in the last century still persist. Advancements in engineering science, equipment improvements, well management and technology have still not solved the two key industry problems. Nearly 65% of the world's oil resources in existing oilfields is still unrecoverable and trapped in the pore spaces of reservoirs, and the global decline rate now estimated by the International Energy Agency is 6% per year. It is time for a new technology and science to emerge. Organic Oil Recovery,

although a relatively new technology, has had success on 48 oilfields on four continents. This technology has unlocked the science of using microbes to release and recover oil in reservoirs at a low cost and alter decline rates.

The microbial empire

Every day on this planet a hidden group of organisms that cannot be seen, heard or touched allow life on earth to persist. Plants, trees and vegetables cannot grow without them, human and animal bodies cannot survive or digest food without them. These organisms are called microbes, tiny single cell organisms that are one of the building blocks of life itself. 10 million of them can fit on the head of a pin and one teaspoon of garden soil can contain approximately one billion of them.

Microbes have the potential to increase oil production, reduce hydrogen sulfide, alter declines and clean up well bore damage. After 35 years and US\$45 million the solution was found in what is called Organic Oil Recovery (also known as the Titan Process). It has been successfully applied in over 300 well applications averaging 92% production increases onshore and offshore with all-in costs of US\$6 - 15 per incremental barrel recovered.

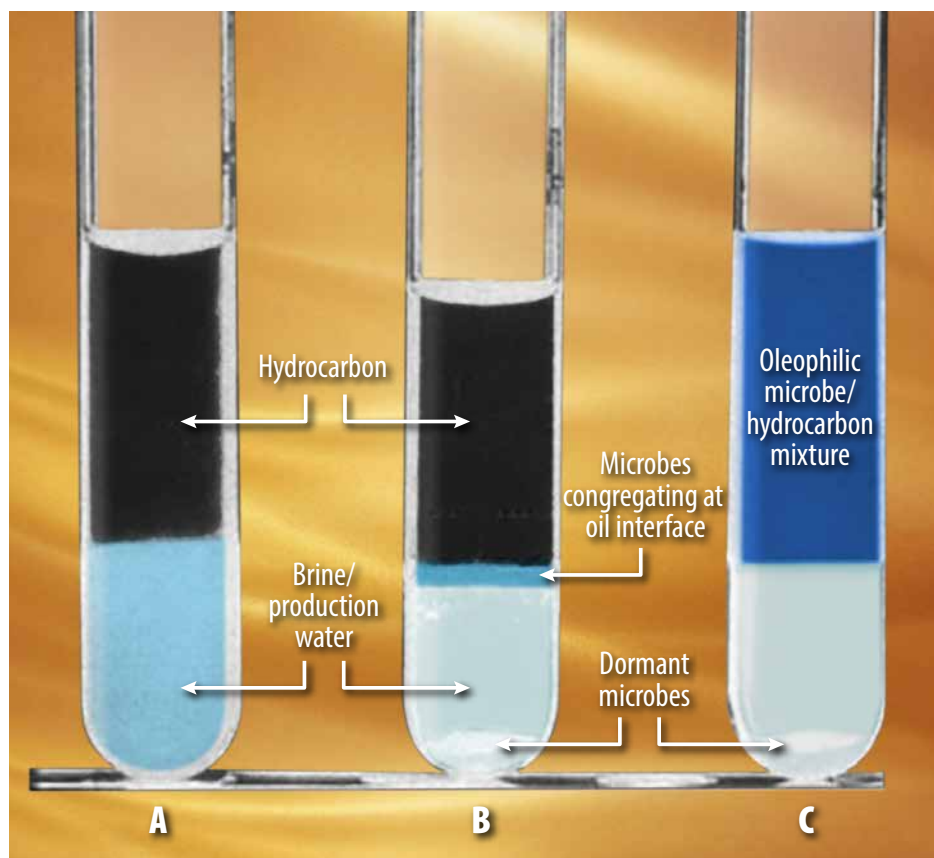
Why microbial-enhanced oil recovery has been unreliable in the past

In the past, scientists tried to harness microbes to mimic standard well management chemical treatments. Instead of injecting surfactants, polymers and acids to help oil production, the focus was on developing microbes that could produce these chemicals after consuming certain foods. This method ran afoul of various natural road blocks including 'mass balance'. If 100 000 lb of something needs to be produced by a living organism, it needs to be fed up to 100 000 lb of food. This method was too expensive, unreliable and ineffective. There are anywhere from 10 - 250 or more species of microbes in a typical oil reservoir's rock structure. With specific microbes developed at surface to create certain in-situ chemicals and then dumped down the well bore with food, other microbes in the reservoir also ate the food. Other microbial methods included injecting molasses and other

sugar compounds to fatten up all the microbes in a waterflood operation, in an attempt to form a large biomass to plug thief zones or high permeability sections of the reservoir rock. Again, it was hit or miss and plugged up oil flows as well.

How does the process work? And how does it differ in harnessing microbes for oil recovery?

Through a series of thousands of experiments, exhaustive research and field testing that has spanned over 35 years, Organic Oil Recovery was developed into a predictable science. The new approach was not only to study the microbial populations but to study the ecology of the reservoir where they lived without oxygen. These studies are part of the new science of looking at extremophile microbes (those that can live in high temperatures, high salt concentrations and high pressure or a combination of all three). From this new research viewpoint a method was devised that allowed certain microbial species to create physical, rather than chemical changes in the oil/rock/water interfaces. The Titan Process is not a chemical execution process but a physical one where the microbes do not excrete anything, but have a cell wall change and react in the oil-water interface by moving away from the water (becoming hydrophobic) towards the oil and surrounding and deforming oil droplets and globules into temporary micro-oil droplets.



These test tubes were photographed in our lab. A small amount of production water and oil was added to each test tube. Colors have been digitally added to provide a better understanding of the Titan Process effects.

A: A small fluid sample from an oil reservoir is placed in a lab test tube. The lighter oil rises above the water. There are perhaps 10,000 to 100,000 microbes in the brine/production water (a natural occurrence).

B: A small amount of a tailor-made Titan Process formula, specific only for that reservoir, is added to this test tube. It is agitated for 10-15 seconds and allowed to sit for 36 hours. The microbes consume the special Titan nutrients and have now increased in number to 1-2 billion. They have also vacated the water and have congregated at the oil/water interface. They have become hydrophobic (not wanting water on their skin).

C: The same amount of Titan nutrients were placed in this test tube. Over the next 4-7 days, the microbes have totally immersed themselves into the oil section and have created tens of thousands of micro-oil droplets.

Figure 1: A lab experiment that has been enhanced with colours for better legibility. Here the chronological effect of the microbes in relation to water and oil can be seen.

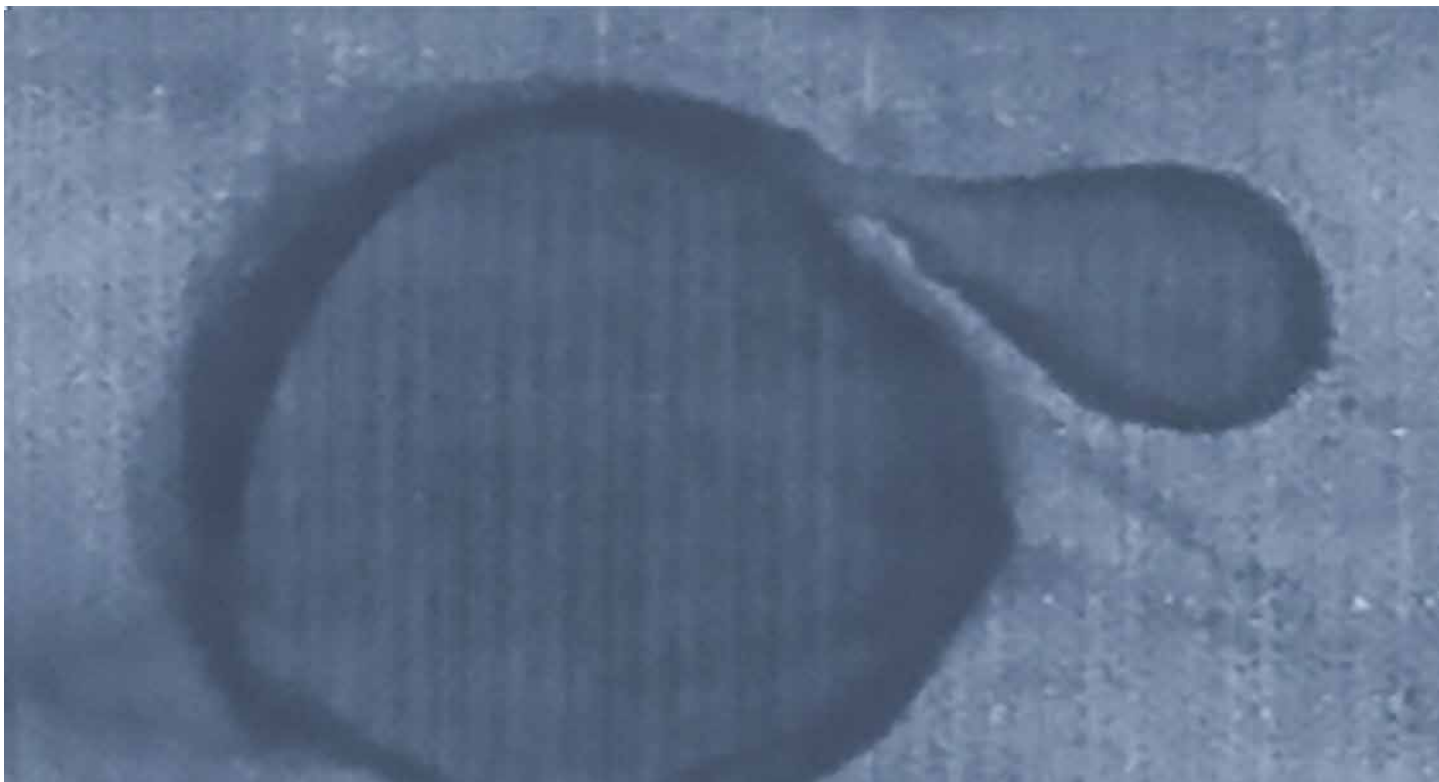


Figure 2: A microscopic photo of an oil droplet being deformed by the process. The section shown being deformed by microbes will also be further reduced to even smaller sections. The temporary micro-droplet creation of oil is a key component of the Organic Oil Recovery science.

Benefits within the oil reservoir

The action of the microbes creates various beneficial changes in the pore matrix of the reservoir. For one, the fact that microbes miles under the surface are actually moving around in the pore spaces creates energy within the pore space (as opposed to energy being applied from the surface miles away). This local energy helps create movement of fluids within the pore spaces. Fluids moving from one pore space to another with the help of microbes, micro-droplets and normal reservoir pressure can create a vacuum in pore spaces where fluids have departed, and since nature abhors a vacuum the adjacent pore spaces with fluids move into those pore spaces. This effect can create an entirely new subset of reservoir fluid movements, that combined with the reservoir pressure gradient moves fluids toward the well bore. The micro-oil droplets also require less energy to flow through the pore matrix. Due to their micro size, the droplets can squeeze through the small pore throats that usually trap larger oil globules.

Microbes, if fed enough food, can grow exponentially. Many species can multiply rapidly. A single microbe can split into two microbes every 20 minutes or so. This means that one cell could become over two billion within 24 hours. The Titan Process creates this army of microbes, which create trillions of micro-oil droplets that can be recovered from producing wells and water flood injection units.

Wettability is altered by the process as oil wet surfaces within the reservoirs have oil being distorted and broken down into micro-droplets. Apparent viscosity is also another factor in improved and enhanced recovery. A large globule of oil with a viscosity rating will flow at a certain rate. If that oil globule is broken down into 1000 tiny droplets, they will not have the same resistance to flow, hence the term 'lowering apparent viscosity'; this helps to move the oil with less pressure towards the well bore.

H2S reduction

This deadly gas is produced by certain species called sulfate reducing bacteria (SRBs). With the process it has been found that H2S levels have reduced significantly. H2S causes corrosion, health problems and sours oil, penalising refinery revenues. The mechanism that takes place with the Titan Process is quite simple to understand. SRBs need to eat and survive on various chemicals in the water of the reservoir rock matrix. But they also have to do something similar to breathing. Just like humans eat food for energy and breathe air to live, these SRBs need to also assimilate or 'breathe' sulfate. In an oil reservoir, various microbial species are getting by with minimal amounts of food in the water.

The specific targeted species that the Titan Process nutrient package is meant for multiply dramatically as referred to above, and their vast numbers crowd out the SRB population from their natural food source, meaning that H2S is reduced.

The combination of the micro-droplets, wettability changes, viscosity improvements and H₂S reduction are very positive results from this process. Improved oil mobility, improved pore to pore displacement of fluids and the reduction of the interfacial tension of oil to rock and oil to water all contribute to positive oil recovery changes in the reservoir. The changes are increased oil production, lower water cut, reduction of H₂S and an altering of the decline rate, allowing for a reserve upgrade after a certain period of time.

Implementation

The process is designed to allow for a low risk and gradient observation for success. It consists of five steps that can be completed within a short period of time. The five steps are geared to allow for the positive management of the ecology and biology of a reservoir.

- ▶ Field review to see if the reservoir is within the technical parameters of the process. It is estimated approximately 50% of the world's oilfields would be amenable to the process.
- ▶ Water samples from the reservoir are analysed in the lab for ecology, biology, DNA and chemical information.
- ▶ If the lab work is successful in designing a nutrient formula for that field and the specific species that the process is targeting, then a one well test is implemented. This one well

test is to verify that the positive microbial response in the lab will take place under actual field conditions.

- ▶ A pilot is then planned for a water injection well.
- ▶ Advanced water flood injection pilots and full field implementation.

The process can be applied to fields that are not under waterflood by treating individual wells. The nutrient formula is complex and different for each reservoir depending on various technical aspects as well as the composition of species living in the reservoir. Every reservoir has a unique ecological and microbial signature depending on geology, temperatures, pressure, pH, salinity and chemicals within the water.

Oil recovery sweet spot

- ▶ Oil gravity from 16 - 42 API.
- ▶ Water pH between 6 - 8.
- ▶ Reservoir temperature: areas in reservoir at less than 95°C.
- ▶ Formation water salinity of less than 140 000 ppm TDS.
- ▶ Reservoir porosity of more than 20% of formation volume (higher the better in general).
- ▶ Reservoir permeability can be less than 1 mD (higher the better in general).

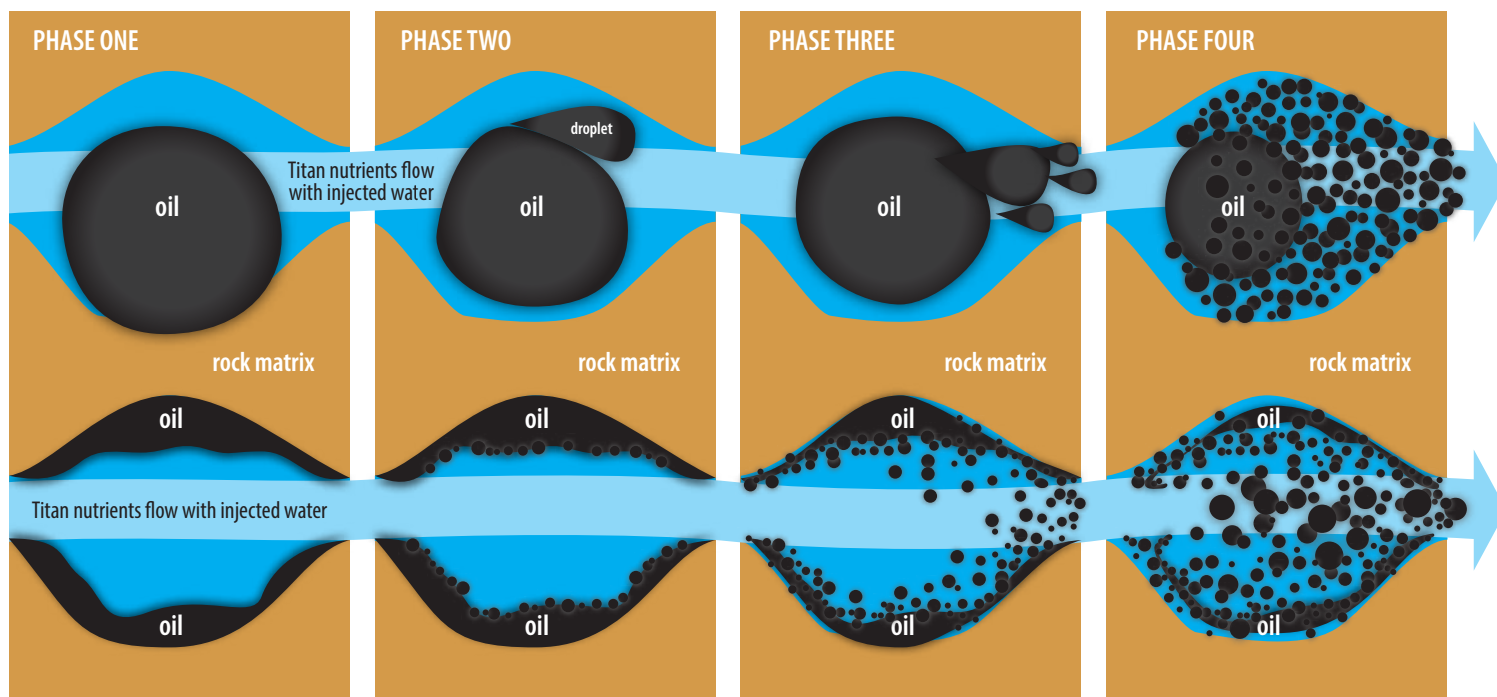


Figure 3: Creating micro-oil droplets allows trapped oil to flow more easily through the tight reservoir pore spaces. The interfacial tension between oil and water and the oil and rock surface is also reduced by the action of the microbes surrounding the micro-oil droplets.

Case studies

The process has been implemented onshore and offshore with over 300 commercial well applications on 48 oil fields. Three oil operators wrote four peer-reviewed SPE Papers on the success of the Titan Process from three oilfields in Canada, Texas and California. The SPE papers are as follows:

- ▶ SPE 124319: MEOR Success in Southern Saskatchewan: Husky Energy: Documents oil production increases of: 225%, 450%, 100% and 533% on various test wells.
- ▶ SPE 129742: MEOR Success in Southern California: Venoco Inc.: Documents oil production increases of: 300%, 15%, 27%, and 752% on various well tests in Southern California.
- ▶ SPE 145054: What Has Been Learned From 100 MEOR Applications: Husky, Venoco, Titan Oil Recovery: 100 Applications documenting an average oil production increase of 127% from pre-treatment rates to post-treatment maximum rates.
- ▶ SPE 154216: A Texas MEOR Application Shows Outstanding Production Improvement: Atinum E&P, Inc. documents oil production increases ranging from 25 - 90% with a dramatic reduction of water cut.

In these documented applications of the process, substantial oil production increases sometimes lasted for more than a year from a single application. The applications were conducted under various reservoir conditions of oil gravity, temperature, salinity, viscosity, porosity and permeability. Including the global applications on injector wells, the process was successful at improving oil production in 98% of injector well applications performed to date.

Conclusion

The problems of trapped oil, steep production declines, excessive water production and H₂S have been a costly and persistent negative aspect of oilfield production for over a century. The biodegradable process of Organic Oil Recovery allows for a new approach to these problems with a proven science and an elegant low-cost solution available to a significant number of global oilfields.



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