Microbes aid heavy oil recovery in Venezuela

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Microbial products present an alternative for increasing production in oil wells that exhibit skin damage, paraffin problems, as-phaltene agglomerates, scaling tendencies, and corrosion con-cerns.

As an example, treatments with biotechnology products have enhanced heavy oil recovery in 25 Lake Maracaibo wells operated in the Petroleos de Venezuela SA Lagunillas district.

Three different reservoirs, LGINF-07, BACH-01, and BACH-67, were treated with microbial solutions (Table 1). These reservoirs produce heavy 10-19° API gravity crude.

Since the early 1920s, Venezuela has been recovering oil from Lake Maracaibo. Today, lake Maracaibo has more than 7,000 wells, in water depths of up to 130 ft, produc- ing ostly on gas-lift (Fig. 1).

Microbes

The microbial treatments in Lake Maracaibo included:

- Para-Bac/S for controlling paraffins
- Ben-Bac for preventing asphaltene deposition and improving crude oil flow properties
- Corroso-Bac for protecting downhole and surface equipment from corrosion by sequestration, filming, and removing solids.

The products are naturally occurring, nongenetically engineered microorganisms that are nonpathogenic to humans.

Small well head platforms are common in Lake Maracaibo (Fig. 1).

A triplex pump on a self-propelled barge was used to inject the microbial treatments (Fig. 2).

These biotechnology products are not chemical products, but their metabolic byproducts react similarly to chemicals.

In the well bore and deep in the formation, microbes work to enhance oil recovery. Living in the water phase, microbes colonize at the oil/water inter- faces in the well bore and cling to porous media, especially water-wet reservoir rock. The microbe-inoculated fluid is pumped into the well bore and out into the formation where colonization and outward mi-gration occur.

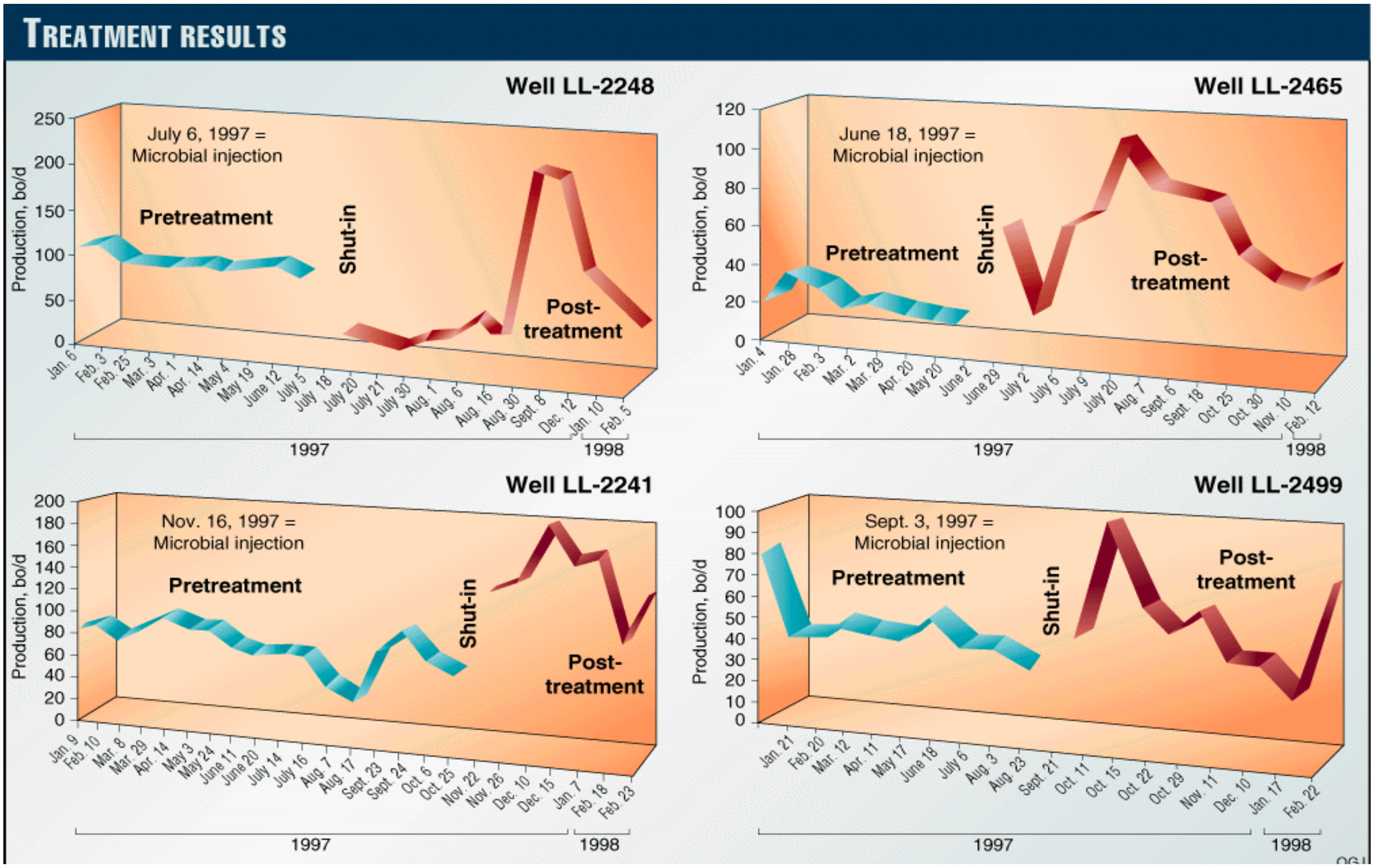
As production fluids flow through the microbe colony, the microbes produce biosurfactants, fatty acids, paraffin solvents, and gases, which are highly effective in mobilizing crude oil.

Workers pour a microbial scale and corrosion inhibitor into a mixing tank (Fig. 3).

The microbes reduce paraf- fin accumulation, asphaltenes agglomerates, and other prob- lems in the well bore area as well as the reservoir. During the stimulation treatment, bio-
produced surfactants and solvents decrease oil/water interfacial tension, altering effective permeability of oil by changing wettability characteristics, and lowering fluid surface tension.

Microbial byproducts also:

- Inhibits scale formation



and corrosion

• Increase API gravity with bio-produced solvents, al-cohols, and ketones.

Microbes significantly de-crease nutrients available for sulfate-reducing bacteria. SRB colonies are lessened or elimi-nated.

The microorganisms can convert long chain n-alkane molecules into less-dense, short- chain molecules, which improves hydrocarbon mobili-ty.

Application

Annular batch treatments and formation squeezes are two of the most common methods or applying micro-bial products in producing oil wells. The selected method de- pends on treatment goals and well characteristics.

Annular batch treatments are intended to reduce well maintenance, while microbial squeeze programs aim to im-prove production from the for-mation.

In the 25 treated oil wells in Lake Maracaibo, the bottom hole temperatures ranged from 130 to 150° F. Microbial products can be effective in bottom hole temperatures of up to 270° F. The selected treatment method was a high-volume microbial squeeze.

Microbial solution was in-jected with a tubing squeeze procedure that placed the solu-tion about 1-2 m into the pro-ducing formation. The solu-tion was injected with a triplex pump from a self-propelled barge docked by the produc-tion platform (Fig. 2).

Solution preparation

The microbial solution con-tained tillered water from Lake Maracaibo and potassium chloride.

The barge holds 650 bbl of solution in two compart-ments—500 bbl in the bottom compartment and 150 bbl inthe top. The solution was pre-pared at the well site (Fig. 3).

To remove suspended

RESERVOIR CHARACTERISTICS

Reservoir	LL-07	Bach-01	Bach-67
Year discovered	1926	1934	1979
Total number of wells	974	481	10
Monthly oil production, 1,000 bbl/month	1,107	1,116	23
Monthly gas production, MMcf/month	858	961	30
Monthly water production, 1,000 bbl/month	820	434	36
Producing area, acres	31,639	23,511	5,185
Net sand thickness, ft	68	137	43
Oil volume, acre-ft	2,117,433	3,229,928	190,385
Porosity, %	30	33.5	33.5
Permeability, md	1,500	3,000	3,000
Distance between wells, m	173	300	300
Geological period	Miocene	Miocene	Miocene
Original oil in place, million bbl	3,828.00	6,621	391
Ultimate oil recovery, million bbl	203	720	35.3
Recovery factor, %	39	16	10
Waterflood in progress	Yes	No	No
Bottom hole temperature, °F.			137
Number of reservoirs	1	1	1
Reservoir depth, m	3,800	3,000	3,300
Deepest well, m	4,700	3,600	3,500
Lithology	Sand	Sand	Sand
Number of sands	3	9	1
°API Gravity	18	12	4

Treatment description

Well	Date	Reservoir	°API	Para-Bac/S, drums	Corro-so-Bac, drums	Ben-Bac, drums	Water, bbl	Shut-in, days	Concen-tration, ppm
LL-2792-3*	04-22-97	BACH-67	13	3	1		500	10	10,000
LL-2609	04-24-97	BACH-67	11	2	2		500	10	10,000
LL-153-2	04-25-97	BACH-01	13	4	4		1,000	10	8,000
LL-2465*	06-26-97	LGINF-07	15	4	3		500	10	18,000
LL-2141*	06-27-97	LGINF-07	17	5	3		600	7	18,000
LL-124*	06-27-97	LGINF-07	18	5	3		600	7	18,000
LL-2105*	06-27-97	LGINF-07	18	3	2		400	7	13,000
LL-2599	07-05-97	BACH-01	11	3	3	2	600	7	18,000
LL-2248	07-05-97	BACH-01	11	3	4	3	800	12	18,000
LL-2772	07-03-97	BACH-01	10	3	3	2	600	15	18,000
LL-2318	04-25-97	BACH-01	10	4	2		600	12	18,000
LL-2624	07-06-97	BACH-01	11	3	4	3	800	15	18,000
LL-2785	07-06-97	BACH-01	11	3	3	2	600	8	18,000
LL-2499	10-03-97	LGINF-07	19	3	2		150	5	54,000
LL-2647	10-03-97	LGINF-05	18	4	3		200	5	54,000
LL-2214	10-17-97	LGINF-07	19	3	1		100	5	54,000
LL-360	10-17-97	LGINF-07	15	3	1		100	5	54,000
LL-1506	10-17-97	LGINF-07	14	3	1		100	5	54,000
LL-2106	10-18-97	LGINF-07	19	5	3		200	5	54,000
LL-1359	10-18-97	LGINF-07	15	5	3		300	5	36,000
LL-1579	11-03-97	LGINF-07	16	3	1		100	5	54,000
LL-1634	11-16-97	LGINF-07	18	4	3		250	5	43,000
LL-2231	11-16-97	LGINF-07	19	3	2		150	5	54,000
LL-2241	11-16-97	LGINF-07	19	4	3		250	5	43,000

*Surfactant was added

solids prior to mixing, the lake water was strained through a 2-micron filter. The water (100 bbl) was pumped into the top holding tank where a centrifugal pump mixed the potassium chloride (KCl) and microbial products with lake water.

Powdered KCl concentrate was mixed at a concentration of 1.6% by weight, while the microbe concentration ranged from 8,000 to 54,000 ppm. Microbe concentration depends on the well shut-in time. The longer the shut-in, the lower the concentration.

The solution was transferred to the 500-bbl compartment after each 100 bbl was prepared. This procedure was repeated until the desired volume was prepared.

The thoroughly mixed solution was then transferred in 100-bbl intervals to the top compartment from which it was injected into the well with a triplex pump.

Injection procedure

The microbial solution (Table 2) was injected at a rate of 3 bbl/min at a pressure greater than the well's bottom hole pressure. Care was taken so that the injection pressure did not damage the formation.

The wells were then shut in between 5 and 15 days to allow the microbial colony to become established.

The solution in the first wells had low microbe concentrations, and the wells were shut in for longer periods. Because the operator preferred shorter shut-ins, the subsequent wells had higher microbe concentrations, and shut-ins were reduced to 5 days.

After the shut-in period, the wells were returned to production.

Testing and well data records were kept to provide on-going monitoring analysis. Data included:

- Whole oil/gas chromatography
- Saturates, aromatics, resins, and asphaltenes analysis
- Water analysis
- Viscosity, pour-point, and cloud-point analysis
- Testing procedures specific to microbial products.

Additional treatments

An optional proprietary surfactant was added to five of the treatments. The advantages of the surfac tant include deeper penetration into the oil-bearing formation, faster production increases, and decreases in interfacial tension.

When microbes penetrate the oil-bearing formation, the speed at which they migrate away from the well bore is inversely related to the formation obstacles that they encounter. The surfactant increases the penetration rate by removing various obstacles that slow down the penetration rate of the microorganisms.

Wells with a long history of chemical treatments may be more difficult to treat successfully with microbes. Poor results might be obtained because chemical residuals in well casing could be toxic to some microbial products.

Depending on chemical residuals in the well casing, a higher treatment dosage may be called for, or the well may need an additional treatment.

Results

Fig. 4 shows the production performance of four of the treated wells. Each well had a significant production peak several weeks after the treatment.

Of the four wells. Well LL-2241 shows the most sustained production after the treatment.

Overall, the three reservoirs had an 80% success rate, with increases in oil production of 50-200%, indicating that microbes are an alternative to traditional treatments.

The Authors

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