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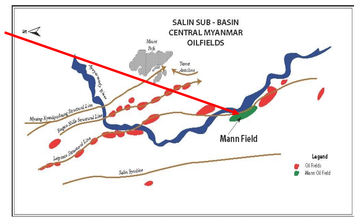
EEOR Success
Mann Field, Myanmar

William K. Ott, P.E., SPE, Well Completion Technology
Thu Nyo, SPE, MPRL E&P Pte Ltd
Win Nyunt Aung, SPE, MPRL E&P Pte Ltd
Aung Thet Khaing, SPE, MPRL E&P Pte Ltd

Enzyme Enhanced Oil Recovery (EEOR)

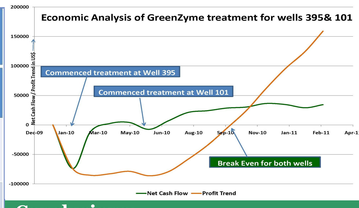
- EEOR - acronym for Enzyme Enhanced Oil Recovery
- EEOR - GreenZyme®, water-soluble enzyme, first applied in 1999 , different from microbes in EOR and not chemical polymers used in EOR

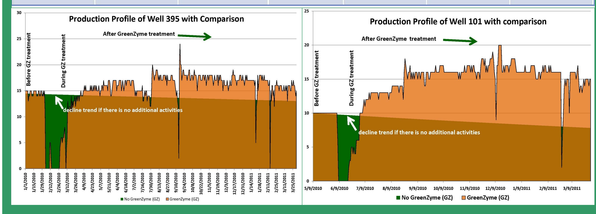
- Mann Field is located in Salin sub-basin of the central basin of Myanmar in Southeast Asia and currently is operated by MOGE, with MPRL E&P Pte Ltd as contractor for field operations management
- Field, consisting of 26 stacked sandstone payzones, began production in 1970
- More than 667 wells have been completed, and 118 million stock tank barrels of oil produced
- Average porosity of field is 18% with an average permeability of 10-250 md
- Two test wells in this mature oil reservoir, Well 395 and Well 101, were treated with EEOR process, which resulted in increased oil production
- EEOR is a concentrated, water-soluble enzyme preparation made from DNA-modified proteins released from selected microbes
- Well 395 was treated first with four drums of enzyme solution in filtered, 2% KCl water and recovered load was then used to treat Well 101



- Pretreatment production from Well 395 was 14 bopd and 2 bwpd; current production is 18 bopd, and some 530 incremental barrels have been produced in 13 months since treatment
- Well 101 was at 10 bopd and 109 bwpd; current production is 16-17 bopd, and approximately 1636 barrels of incremental oil during nine months since treatment
- These two successful EEOR applications are allowing for treatment design improvements in future wells with higher current oil productivities

Well Number	Production Decline (%)		Water Cut (%)		Production Rate (avg bopd)	
	Before	After	Before	After	Before	After
395	8.36	flat	17.6	23.8	14	17
101	27.8	flat	90	90.4	10	16



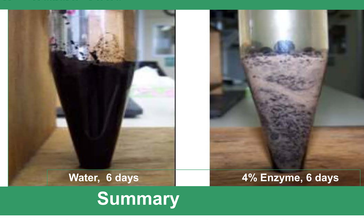


Conclusions:

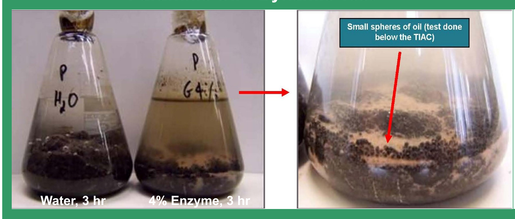
- Application of modified enzyme in Mann Field improves oil production
- Modified enzyme solution can effectively be recycled into other wells to enhance production
- Treating higher impact wells should result in greater profitability
- Diverting modified enzyme treatments into more intervals should improve treatment results
- Arresting decline rate after treatment is significant result from this test
- Preliminary tests indicate it is more effective in high water cut wells

Evaluation of the Effectiveness—Heavy Oil—Static Test *

- Acts on wettability of rock. Adsorbs grains and expels oil that is adhered to them. Makes rock strongly wet by water.
- Oil stuck to rock has to have *mobility*. It may not be in solid state, otherwise enzyme cannot release it from surface of grains.
- In case oil condition is *immobility,* it will be necessary to heat formation or inject solvents.
- According to supplier, it does not crack hydrocarbons. Enzyme does not form emulsions and is insoluble with oil.



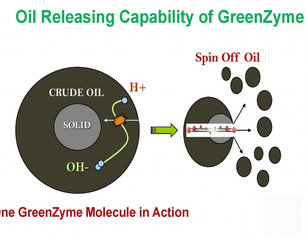
Paraffinic Oil—Dynamic Test

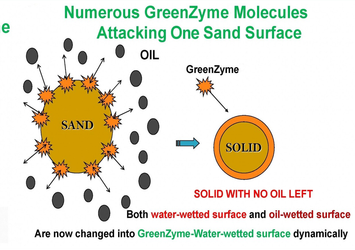


Summary

- Enzyme can effectively move oil from surface of grains of sandstone, provided that these hydrocarbons are above point of fluidity.
- Mechanism of operation seems to be a reversal of wettability, making grains strongly wet by water.
- Enzyme diluted to 4% showed satisfactory performance in sand contaminated with heavy oil, both paraffinic and asphaltic.
- Submitted to extreme conditions of pH, temperature, salinity and shearing, enzyme continues to function that, albeit slower. Temperature limit tested was 200°C.
- Enzyme presents instability, a forming a precipitate after resting for a few days. Presence of divalent cations seemed to have aggravated problem.

GreenZyme — What is it?

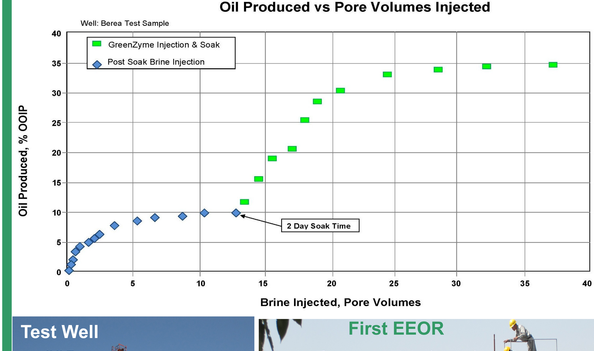




Is an enzyme, a protein-based

It has **two** main uses: For **Enhanced crude Oil Recovery**, i.e. EOR. For **remediation of oil contaminated solid wastes**.

General comment on GreenZyme: Non-toxic; near neutral in pH (5-7); non-pathogenic. Biodegradable; environmentally friendly.



TYPES OF WELLS

- Both vertical and horizontal wells.
- Single well booster application.
- Multiple wells flooding applications.
- Sandstone formation : GreenZyme only.
- Limestone formation : GreenZyme plus acid.