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High Molecular Weight Organic Scale Near Wellbore Improved Oil Recovery

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Abstract

Oil production from the field begin with the first oil in January 2003. Unfortunately, the wells produced viscous emulsion which caused the production decline rapidly. Further analysis of the production data showed that the decline in production over a long period of time is very consistent with organic deposition at or near the perforation interval.

Over the years, several analyses and production enhancement efforts including chemical and mechanical treatments have been attempted with minimal success. The damaging mechanism was determined to be caused by rare High Molecular Weight Organic Deposit (HMWOD) that have caused a significant pressure drop in the tubing, which consequently restrict oil production and tested to only disperse at above 90°C. It was suspected that the deposit was a naturally-occurring component of the crude oil itself, separating from the bulk of the crude as a consequence of the fluids movement towards the wellbore and the consequent drop in fluid pressure.

An eco-friendly nano-fluid was developed and pilot treatment conducted in February 2014, which successfully rejuvenated the well back to production. Subsequent treatment was conducted in early 2018 on the same well and later replicated on another well as part of technology maturation process. This paper incorporates laboratory tests conducted to customize the nano-fluid, engineering approach on the treatment volume, simulation analysis on treatment schedules, treatment procedure as guidance for offshore personnel and actual field result of the treatments.

Remedial treatment for near wellbore HMWOD using novel nano-fluid has successfully revived the wells back to production. Further development and replication would open-up bigger opportunities to unlock potential of wells with similar organic deposit issue throughout PETRONAS' operation.

Introduction

The field located 40km Northwest Offshore Sarawak, at water depth of 259ft below Mean Sea Level (MSL). It was discovered in August 1998 with the exploration drilling of Well #1. The Field Development Plan

(FDP) comprises of one development well penetrating clastic Reservoir A, B and C. The Reservoir A was entirely oil bearing while the Reservoir B encountered a clearly defined oil-water contact. The drive mechanism for both reservoirs A and B is solution-gas with moderate aquifer support, whilst Reservoir C has water-bearing poor quality shally sand (Figure 1).

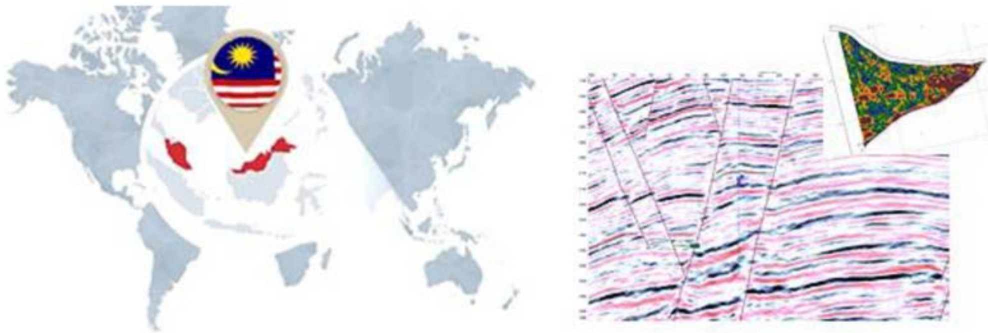

Figure 1—Location map of the field

Development Well #2 was positioned slightly to the South from center of the reservoirs at an elevation of 8,860ft, to encountered area of high amplitude that seen in the reservoirs and away from the A and B faults that have a high probability to act as impermeable barriers. It was drilled from nearby matured field platform, located 2.5km to the Southeast, where the fluids were commingled before it is sent to the existing piping for separation and processing (Figure 2).

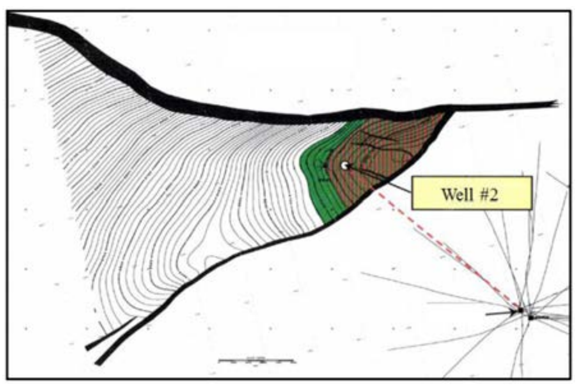

Figure 2—Depth structure map of Well #2

It was completed in January 2003 as dual string oil producer using 2-3/8" K-Fox, L-80 4.6ppf tubing inside 7" BTC, L-80 26ppf liner with Short String (SS) completed in Reservoir A and Long String (LS) completed in Reservoir B. Permanent packer set above Reservoir B and a dual hydraulic packer set above Reservoir A, the separation of the dual completion will enable proper reservoir management throughout the field life (Figure 3).

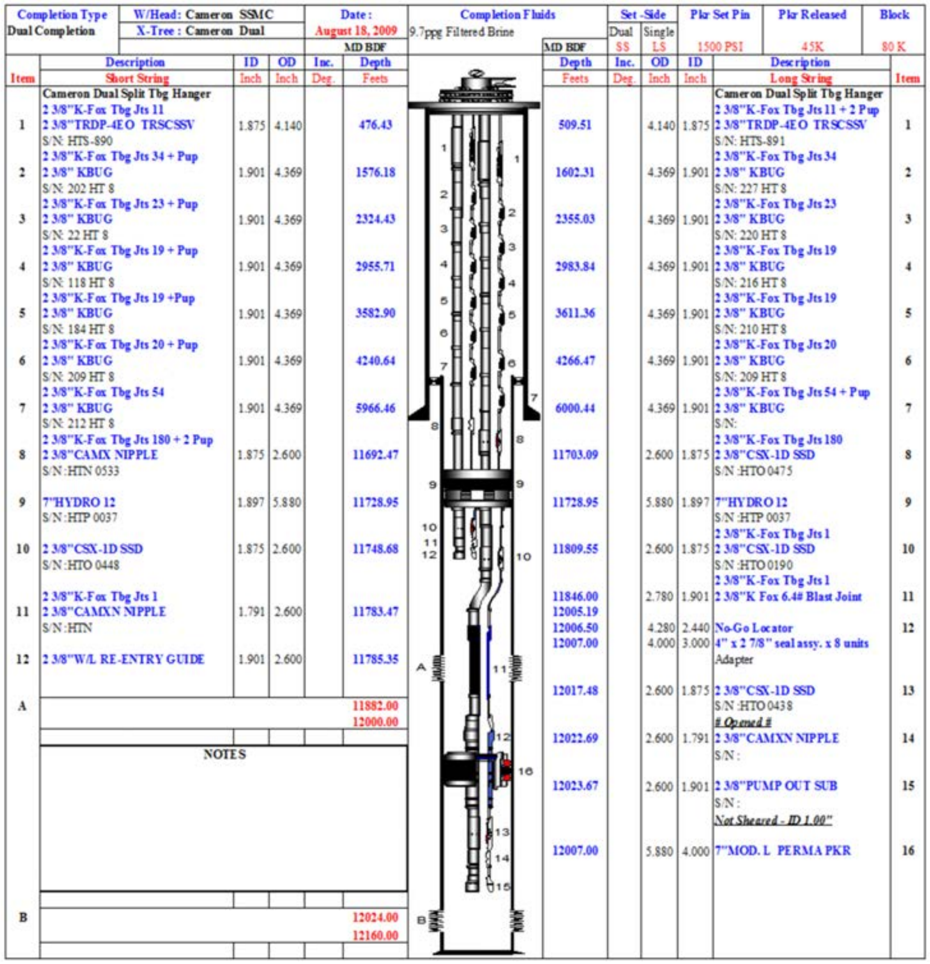

Figure 3—Schematic diagram of Well #2

Table 1—Well #2 information and parameters

Well #2	Short String	Long String
Reservoir	Reservoir A	Reservoir B
Formation Type	Sandstone	
Zone Interval, ft-MDBDF	11,882 – 12,000	12,024 – 12,160
Reservoir Pressure, psi	3,800	2,750
Reservoir Temperature, °C	94	97
Average Porosity, %	18	17
Average Permeability, mD	10	10
Completion Type	Dual String Oil Producer	
Production Tubing	2-3/8” K-Fox, L80 4.6ppf	
Production Casing/Liner	7” BTC, L-80 26ppf	
PBTD, ft-MDBDF	12,360	

Well #2 production started to drop rapidly towards the end of 2003. Multiple production enhancement efforts, including chemical and mechanical treatments, conducted over the years with minimal success.

Identification of Damage Mechanism

The damage cannot be removed by acid treatment, thus appears to be organic in nature. Further analysis of production data showed that the decline over a long period of time is very consistent with organic deposition at or near the perforation interval. Likewise, experiment result showed presence of substances in the crude with the ability to emulsify oil and water to form sticky deposit that gives the possible explanation of very stable emulsion problems on surface (Figure 4).

Figure 4—Stable emulsified crude and sticky deposit

Lab studies documented in June 2012 concludes that there was a presence of High Molecular Weight Organic Deposit (HMWOD), exist at temperature greater than 90°C, that have caused a significant pressure drop in the tubing and consequently restrict the hydrocarbon production from the reservoir into the wellbore (Figure 5).

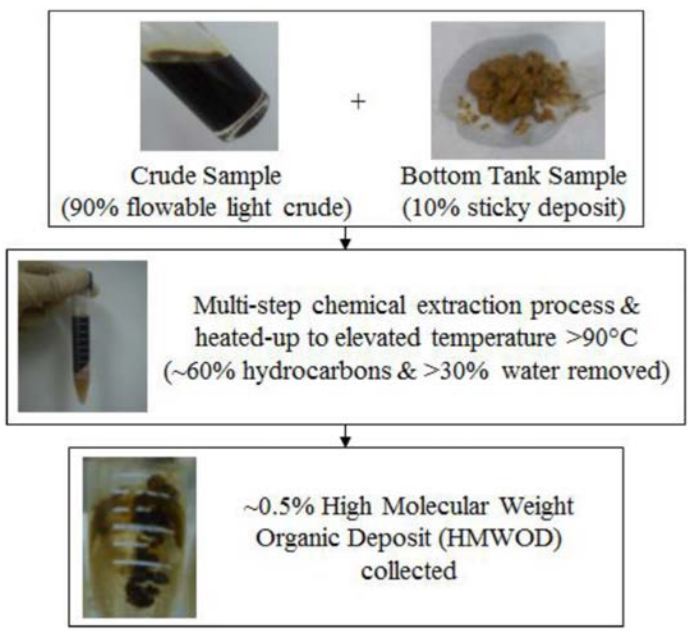

Figure 5—Multi-step chemical extraction process

These deposit was a naturally-occurring component of the crude oil itself, separating from the bulk of the crude as a consequence of the fluids movement towards the wellbore and the consequent drop in fluid pressure. As such, nano-fluid pilot treatment was considered to rejuvenate the wells back to production.

Nanoemulsion Surfactant

Nanotechnology has had revolutionary impact in many industries and is finding more application in the oilfield to enhanced drilling performance, well deliverability and reservoir productivity. It refers to a field of applied science and technology of matter manipulation on atomic and molecular scale, generally with at least one dimension sized from 1 to 100 nanometers, to accomplished specific purposes. Nanoscale materials properties such as melting point, electric conductivity and chemical reactivity change significantly from those at larger scales (Figure 6).

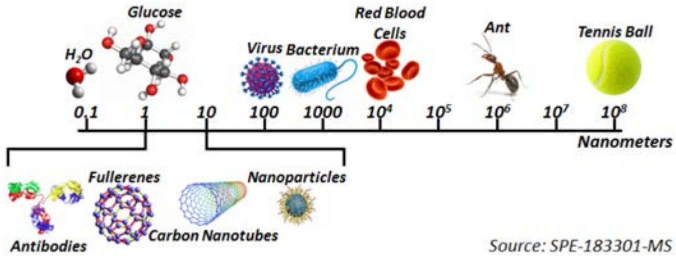

Figure 6—Comparison of length scale

Surfactants are compound that lower the surface or interfacial tension that may act as detergents, wetting agents, emulsifiers, foaming agents or dispersants. Usually organic compounds of two well-defined moieties, the oil-soluble hydrophobic group (e.g. their heads) and water-soluble hydrophilic group (e.g. their tails). Surfactant molecules tend to self-coagulate and form molecular cluster called *micelle*. At Critical Micelle Concentration (CMC), further addition of surfactant will lead to creation of new micelle that reduce surface tension and eventually will form emulsions. Emulsions are not equilibrium system, disperse multiphase system of two or more insoluble liquids that consist of at least one continuous outer phase and one isolated inner phase.

Microemulsions are thermodynamically stable mixtures of oil and water, form spontaneously in the presence of surfactants. In contrast to emulsions, they are form upon right blend of the components that do not require high shear conditions and will not phase separate with time. Microemulsions are single phase system in which the oil and water may adopt a bicontinuous structure or be present in the form of droplets of one phase dispersed within the other.

Nanoemulsions do not form spontaneously as their characteristic and stability depend highly upon the preparation method, order of addition of components and the nature of phases generated during the emulsification process. They have significantly greater surface areas than similar masses of larger-scale materials. As surface area per mass of a material increases, a larger amount of the material can come into contact with surrounding materials, thus affecting reactivity to solubilize large amount of materials without vigorous agitation or turbulence flow.

An eco-friendly nanoemulsion surfactant was developed to remediate Well #2 production, that can disperse HMWOD to clean the near wellbore. It also can act as demulsifier to stabilize the crude and alter the wettability of the formation to more water wet for the easier flow of oil.

Rigorous laboratory testing conducted using the nanoemulsion surfactant showed positive results with the following main findings (Table 2);

1. Manage to disperse the deposit without agitation.
2. Withstand and stable at high temperature.
3. Does not cause clay swelling or secondary precipitation.

Table 2—Summary of chemical evaluation

No.	Sample Condition	Evaluation Objective	Findings
1	Crude sample at room temperature	Evaluate chemical treatment on sticky deposit at room temperature	Nanoemulsion surfactant treat sticky deposit by dispersing and demulsification (**Figure 7**)
2	Crude sample at room temperature	Evaluate inhibition of redeposition of sticky wax during cooling	Sticky deposit is dispersed very well by nanoemulsion surfactant and oil-wet the surface (**Figure 8**)
3	Crude sample at room temperature	Evaluate dissolution rate of sticky deposit at stagnant condition	45 minutes for 95% dissolution with 30% nanoemulsion surfactant and 3.5 hours for 95% dissolution with 100% nanoemulsion surfactant (**Figure 9**)
4	HMWOD emulsion at elevated >90°C	Evaluate chemical treatment on HMWOD emulsion	Nanoemulsion surfactant able to demulsify and disperse HMWOD (**Figure 10**)
5	Dried HMWOD at elevated >90°C	Evaluate chemical treatment on dried HMWOD	Nanoemulsion surfactant able to disperse and making dried HMWOD not sticky (**Figure 11**)
6	HMWOD residue at elevated >90°C	Evaluate static soaking time of dissolving HMWOD	Nanoemulsion surfactant able to dissolve and disperse HMWOD without the formation of sticky deposit after 3 hours static soaking (**Figure 12**)
7	Crude sample (contain HMWOD) in syntactic core at elevated >90°C	Simulate extracting crude oil with HMWOD in sandstone reservoir	Nanoemulsion surfactant effectively penetrate into the syntactic core to extract the trapped oil (**Figure 13**)

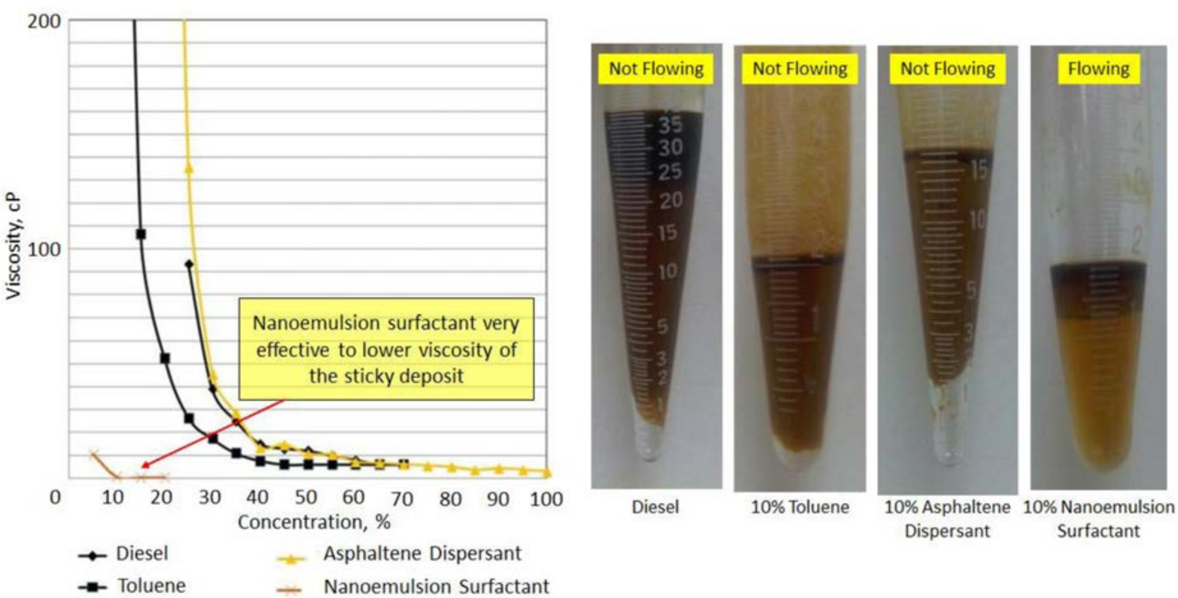

Figure 7—Evaluate chemical treatment on sticky deposit

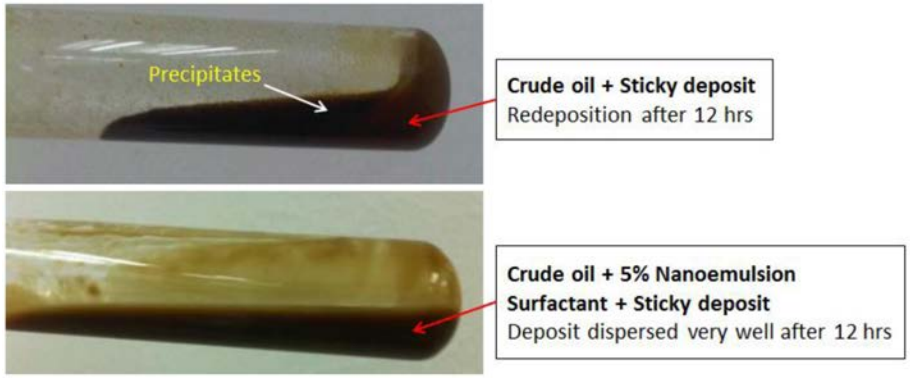

Figure 8—Redeposition inhibition test

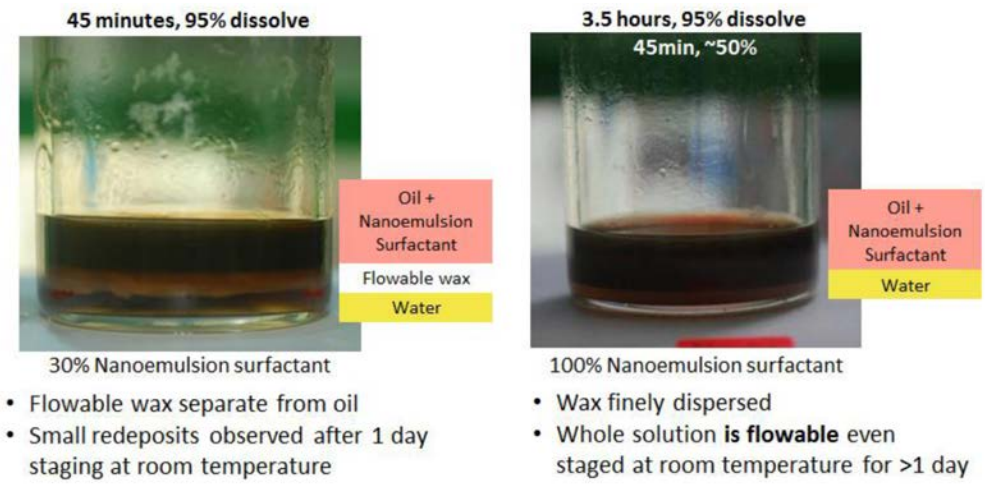

Figure 9—Wax dissolution and redeposition test

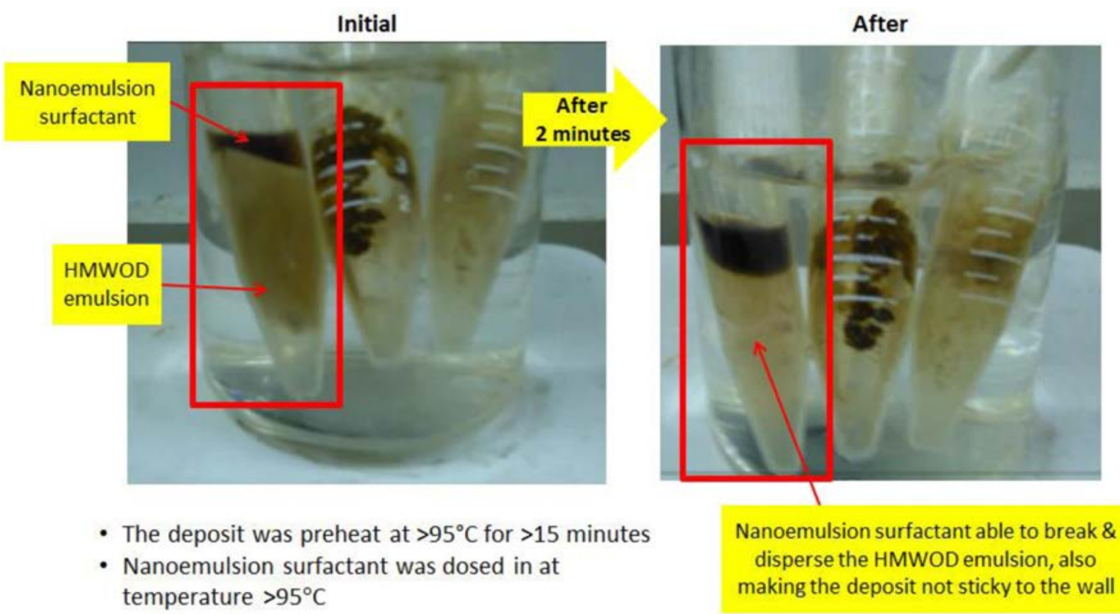

Figure 10—Nanoemulsion surfactant with HMWOD emulsion

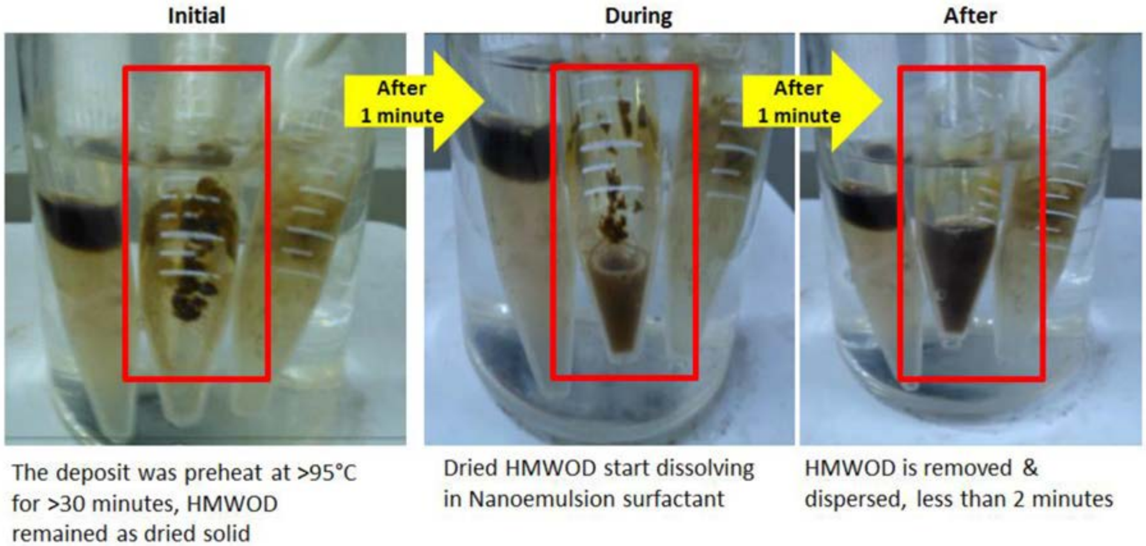

Figure 11—Nanoemulsion surfactant with dried HMWOD

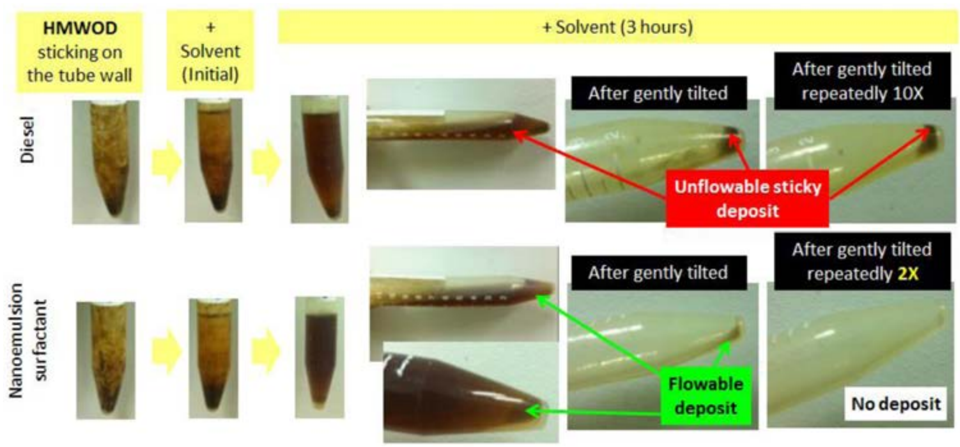

Figure 12—Static soaking test of HMWOD at 90°C

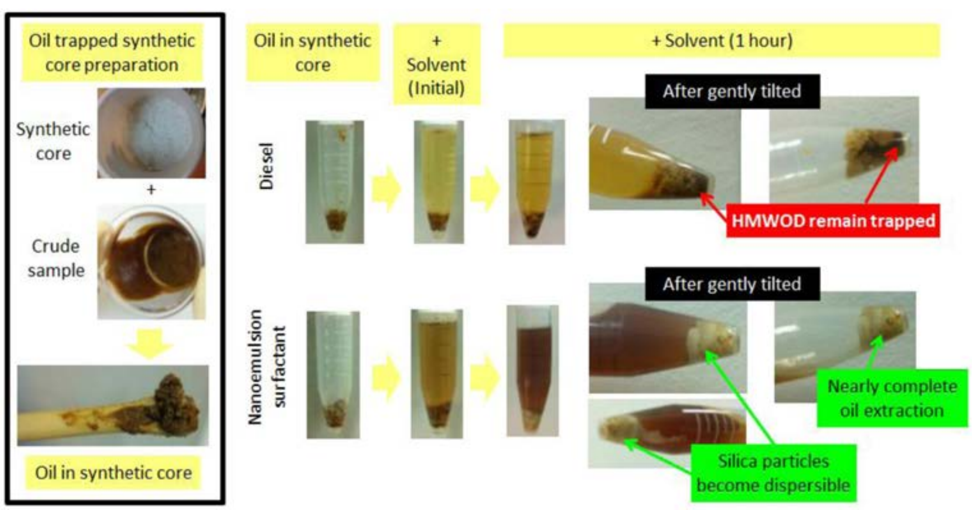

Figure 13—Simulation of extracting the oil trapped in sandstone reservoir

Field Implementation

The treatment was designed to target the near-wellbore critical matrix of 3ft (e.g. most of reservoir pressure drop during production occurs) where injected nano-fluid can restore original permeability.

Remedial Treatment of Long String

The string production started to decline towards the end of 2003, several attempts were made such as Gaslift Optimization (GLOP), chemical stimulation (e.g. include organic and inorganic acid stimulation) and reperforation but the results were unsatisfactory (Figure 14).

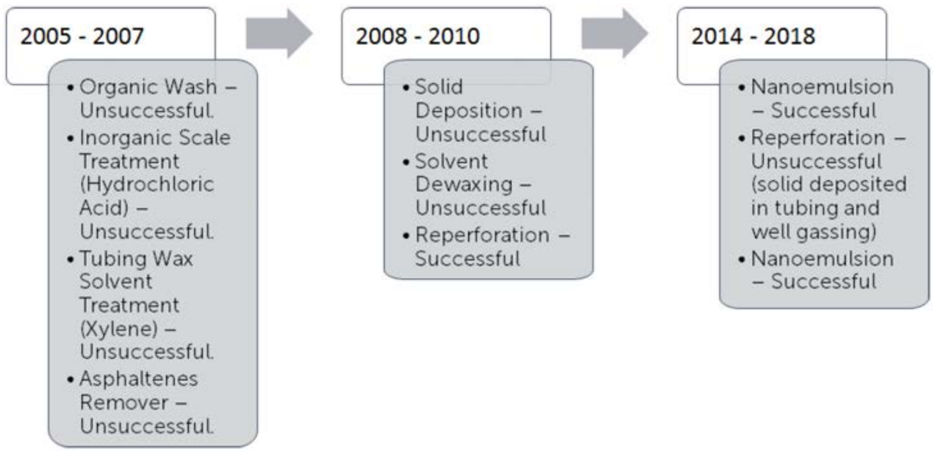

Figure 14—Historical treatment on long string

Pilot treatment conducted in 2014 successfully rejuvenated the string with 42% additional oil production and managed to remove HMWOD in the near-wellbore (e.g. evidence by higher FTHP). It generated a stabilized instantaneous gain back to the previous trend in approximately 9 months. However, the emulsion issue reoccured once all fluid in contact with nanoemulsion produced (e.g. after 500 barrels produced liquid).

Post job discussion suggest tubing soaking and wellbore clearance followed by flowback of the well before proceed with main treatment injection into the near-wellbore. As such, subsequent treatments were conducted in 2018 with improved treatment schedule (Table 3) and higher volume to sustain the production and penetrate deeper into the wellbore (Figure 15).

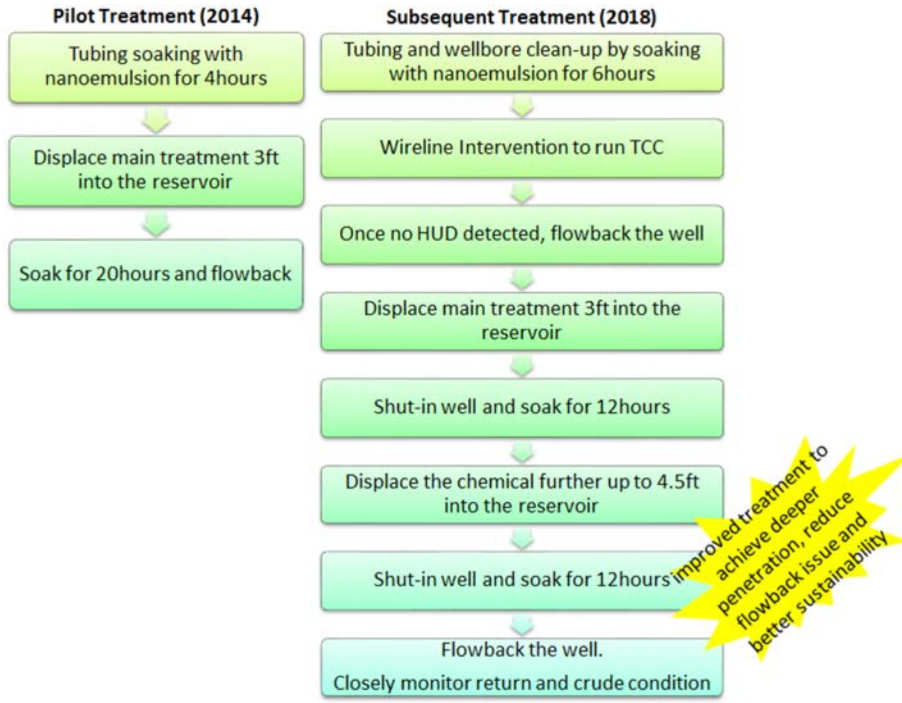

Figure 15—Treatment design and improvement

Table 3—Summary of long string nanoemulsion treatment schedule

2014 Treatment			
Treatment Stage	**Fluid**	**Volume (bbls)**	**Rate (bpm)**
Tubing and Wellbore Clean-Up	Nanoemulsion surfactant	84	0.5 – 1
Shut-in well and soak for 4hours			
Tubing and Wellbore Clean-Up	Nanoemulsion surfactant	84	0.5 – 1
Shut-in well and soak for 4hours			
Tubing Displacement	Synthetic Paraffin	66	0.5 – 1
Shut-in well and soak for 12hours			

2018 Treatment			
Treatment Stage	**Fluid**	**Volume (bbls)**	**Rate (bpm)**
Pre-Flush	Diesel	2	0.5 – 1
Tubing and Wellbore Clean-Up	Nanoemulsion surfactant	10	0.5 – 1
Shut-in well and soak for 30minutes			
Tubing and Wellbore Clean-Up	Nanoemulsion surfactant	10	0.5 – 1
Shut-in well and soak for 30minutes			
Tubing and Wellbore Clean-Up	Nanoemulsion surfactant	10	0.5 – 1
Shut-in well and soak for 6hours			
Post-Flush	Diesel	10	0.5 – 1
Shut-in well and soak for 30minutes			
Post-Flush	Diesel	10	0.5 – 1
Shut-in well and soak for 30minutes			
Post-Flush	Diesel	10	0.5 – 1
Shut-in well and soak for 12hours. Wireline intervention to run TCC.			
Pre-Flush	Diesel	2	1 – 3
Main Treatment	Nanoemulsion surfactant	149	1 – 3
Tubing Displacement	Diesel	46	1 – 3
Shut-in well and soak for 12hours			
Over-Flush	Over-Flush		
Shut-in well and soak for 12hours			

This has successfully revived the string back to production at lower total treatment cost (Figure 16).

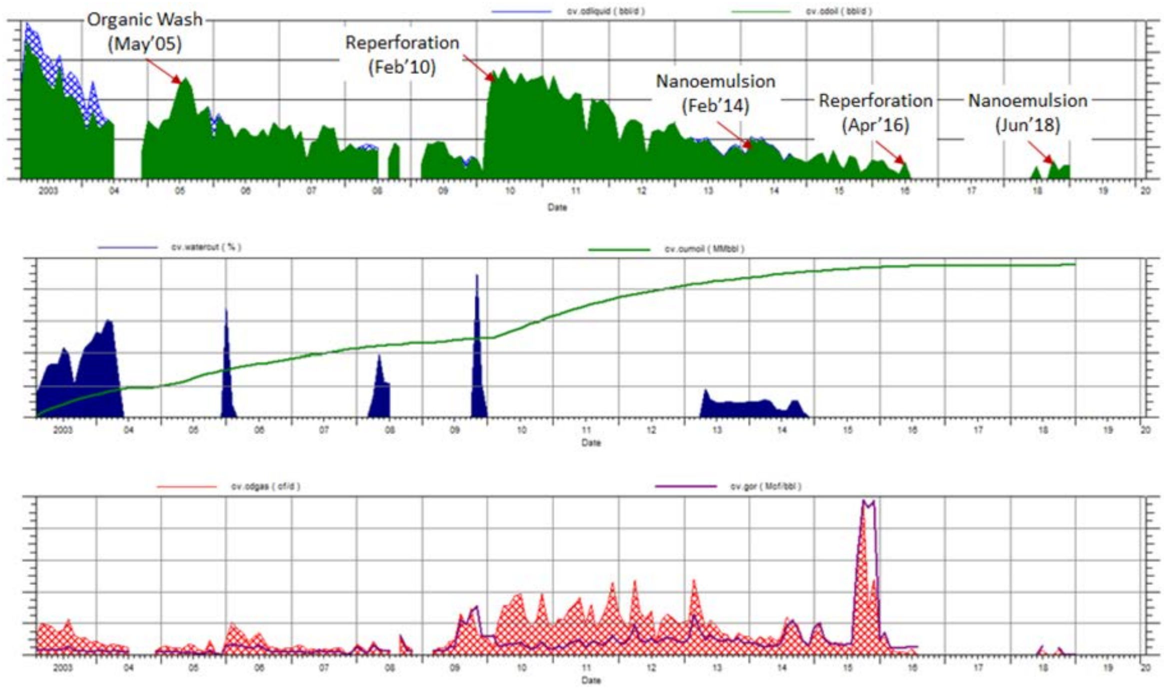

Figure 16—Long string production history

Remedial Treatment of Short String

The string production started to decline towards the end of 2003, several attempts were made such as Gaslift Optimization (GLOP), chemical stimulation (e.g. include organic and inorganic acid stimulation) and reperforation but the results were unsatisfactory (Figure 17).

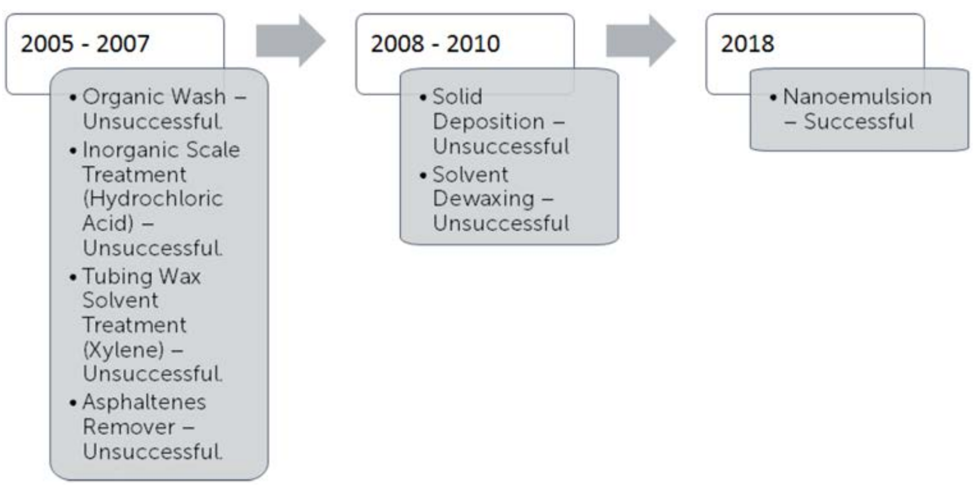

Figure 17—Historical treatment on short string

Consequent from long string treatment, nanoemulsion treatment was replicated in short string (Table 4).

Table 4—Summary of short string treatment schedule

Treatment Stage	Fluid	Volume (bbls)	Rate (bpm)
Pre-Flush	Diesel	2	0.5 – 1
Tubing and Wellbore Clean-Up	Nanoemulsion surfactant	10	0.5 – 1
Shut-in well and soak for 30minutes			
Tubing and Wellbore Clean-Up	Nanoemulsion surfactant	10	0.5 – 1
Shut-in well and soak for 6hours			
Post-Flush	Diesel	10	0.5 – 1
Shut-in well and soak for 30minutes			
Post-Flush	Diesel	10	0.5 – 1
Shut-in well and soak for 30minutes			
Post-Flush	Diesel	6	0.5 – 1
Shut-in well and soak for 12hours. Wireline intervention to run TCC.			
Pre-Flush	Diesel	2	1 – 3
Main Treatment	Nanoemulsion surfactant	140	1 – 3
Tubing Displacement	Diesel	48	1 – 3
Shut-in well and soak for 12hours			
Over-Flush	Diesel	140	1 – 3
Shut-in well and soak for 12hours			

This has successfully regain SS production (e.g. 25% incremental) and thus contributed substantial improvement to the field production (Figure 18).

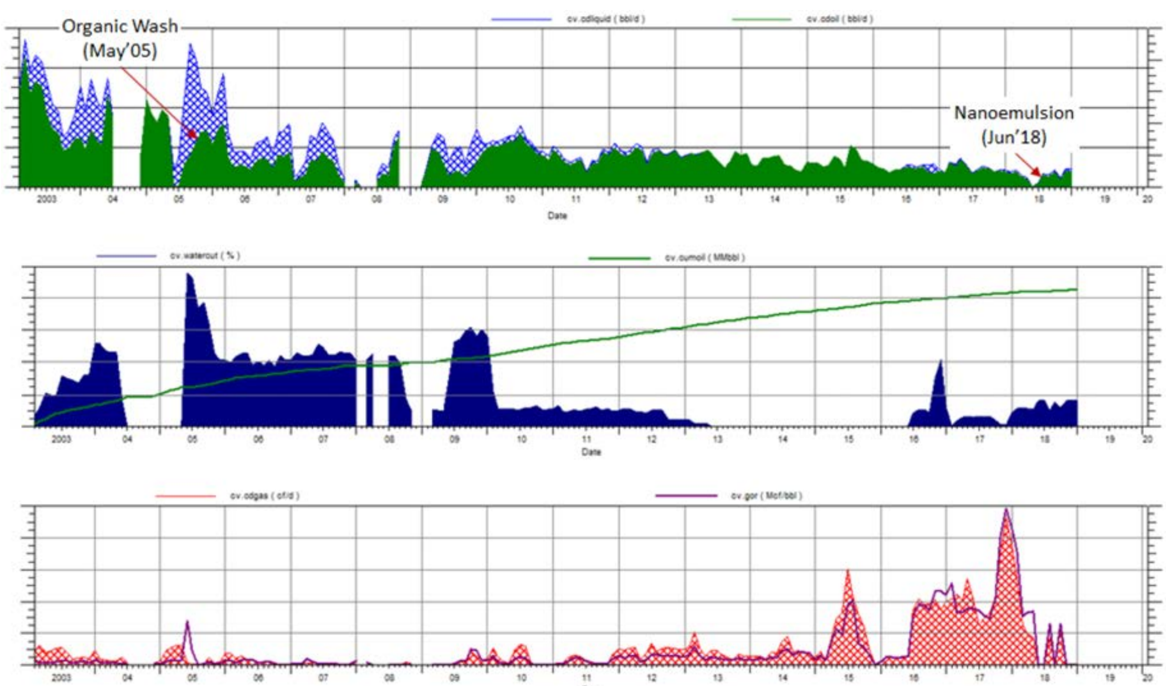

Figure 18—Short string production history

Conclusion

1. The wells suffer damage from the organic scales identified in the recovered deposits and in the laboratory testing.
2. Remedial treatment for near wellbore HMWOD using nanoemulsion surfactant has successfully revived LS from idle back to production and regain SS production at 25% increment.
3. The improved treatment design able to sustain the gain for longer period, at lower total treatment cost and contributed substantial improvement (e.g. 100% increment) to the field production.
4. Further development and replication would open-up bigger opportunities to unlock potential of well with similar organic deposit issue throughout PETRONAS' operation.

Acknowledgement

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