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Modeling Microbial Enhanced Oil Recovery (MEOR) Optimization Augmented with Formation Damage Mitigation Within Sandstone Core Under Adverse Subsurface Oil-Field Conditions

Monday, 30 May 2022 09:40 (1h 10m)

For an efficient field implementation of MEOR process, crucial microbial, formation rock and physicochemical properties, and operational parameters must be characterized and optimized. The present study numerically investigates the impacts of nutrient competition, toxicity, pulse injection time (t_pulse), media heterogeneity, and microbial reversible attachment and detachment rates on tertiary *in-Situ* MEOR mediated with biosurfactant and biofilm production within a sandstone core system under extreme field-like conditions of varying temperature, salinity and brine pH.
Herein, the developed highly coupled multi-species reactive-transport black oil model simulates heat transport; cation and anion transport with multi-component ion exchange (MIE); pH variation with temperature and salinity; injected *Pseudomonas putida* metabolism, and carbon and nitrogen substrate utilization, with maximum specific growth rate being a combined function of temperature, salinity and pH; biosurfactant and biofilm induced oil/water interfacial tension (IFT) and rock wettability alteration (WA), respectively; and capillary desaturation, relative permeability and fractional flow curve variations. Finite difference technique with iterations and error tolerance limit of 10^-7 is used to solve the nonlinear governing equations. MIE-transport is solved by operator splitting and bisection methods.
Verification and validation results determine the present model to be numerically stable and reliable enough. The injected microbe possessing highest specific affinity towards both carbon and nitrogen limiting substrates is clearly found to possess maximum competitive advantage over other microbial populations within sandstone core, thus causing maximal growth and biosurfactant production under extreme conditions. Whereas, the microbes are found to be highly susceptible towards toxic effects of water-soluble organics and indigenous chemicals, reducing growth and biosurfactant production by 70% and 64%, respectively. This loss can be further attenuated by increasing t_pulse for all species just by 1.5 times (38.4 to 57.6 h), thus enhancing biomass and biosurfactant production by 38% and 74%, respectively. Although biofilm formation is important for rock WA towards water-wet condition, in order to prevent formation damage induced by excessive bio-clogging of pore-throats, sandstone core with intermediate heterogeneity is preferred. Formation damage near core inlet can be further prevented by injecting microbes possessing lower reversible attachment-to-detachment ratio, thus attenuating porosity and permeability reduction, and enhancing biomass and biosurfactant production by 10%, 60%, 97% and 35%, re- spectively. Furthermore, temperature (40 to 55 degree Celsius) and salinity (0.32 to 3.15 mol/l) variations had maximal debilitating effect on microbial reactive transport, whereas pH change from 8.0 to 8.9 had marginal impact. The combined effects of IFT reduction (from 25 to 0.001 mN/m) and rock surface WA (from weakly oil-wet towards intermediate wet state) prompted >5 times residual oil saturation reduction (from 60% to <10%), consequently with significant increase in oil relative permeability, fractional flow and recovery for a wide range of oil API gravities (29, 35 and 40 degree API).
Thus, the developed MEOR mathematical model and numerical solution technique at core-scale with lower run time and computational cost proposes an innovative, more realistic and environmentally sustainable strategy for quickly but efficiently selecting suitable microbial and sandstone oil-field candidates for sustainable and profitable MEOR application while simultaneously mitigating bio-clogging induced formation damage.

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Time Block Preference

Time Block A (09:00-12:00 CET)

Participation

Online

Primary author: Mr CHAKRABORTY, Susmit (Indian Institute of Technology Madras, Chennai 36, India)

Co-authors: Prof. GOVINDARAJAN, Suresh Kumar (Indian Institute of Technology Madras, Chennai 36, India); Prof. N. GUMMADI, Sathyanarayana (Indian Institute of Technology Madras, Chennai 36, India)

Presenter: Mr CHAKRABORTY, Susmit (Indian Institute of Technology Madras, Chennai 36, India)

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