Underlying mechanisms and control of oil reservoir souring

JOHN D. COATES [1], ADAM WILLIAMSON [1], HANS CARLSON [1], JUERGEN THIEME [2]

[1] Energy Biosciences Institute, University of California, Berkeley, CA 94704. E-mail: jdcoates@berkeley.edu,
[2] NSLS II, Brookhaven National Laboratory

Biogeochemical H_2S production in oil reservoirs (souring) represents a major risk to personnel safety, ecological disaster, and facility failure. Annual associated cost estimates are in excess of $90 billion globally. Traditional treatment strategies involve nitrate addition to biocompetitively exclude sulfate reducing micoorganisms (SRM). However, success is unpredictable and the mode of inhibition is complex and poorly understood. Our studies have investigated the causes of souring and identified several new treatments that offer more effective and reliable mitigation alternatives. As the first example of these perchlorate shows great promise. We recently confirmed its efficacy as a potent and specific inhibitor of phylogenetically diverse SRM and sulfidogenic communities in oil reservoir simulated systems. We also demonstrated that perchlorate acts as a competitive inhibitor of the ATP-sulfurylase, a highly conserved prerequisite enzyme of the sulfate reduction pathway. In addition to its direct inhibitory effect on SRM, microbial perchlorate respiration is more favorable than sulfate reduction, suggesting that perchlorate will also result in biocompetitive exclusion by dissimilatory perchlorate reducing microorganisms (DPRM). Finally, we demonstrated that all DPRM can alternatively utilize H_2S as an electron donor, oxidizing it to elemental sulfur.

More recently, we investigated tungstate as a potent and specific inhibitor of SRM. Unlike perchlorate which is a competitive inhibitor of the ATP-sulfurylase, tungstate is a futile substrate for the enzyme. Furthermore, tungstate is not used as an alternative electron acceptor, so souring control is mediated soley by SRM toxicity. Evenso, our results indicate that tungstate inhibition is robust in both pure culture and sulfidogenic communities in oil reservoir simulated systems. As part of this we noted that aqueous solubility impacts tungstate's effectiveness. Using X-ray spectroscopy, we characterized the underlying biogeochemistry and developed an understanding of the controlling mechanisms. Using this information we were able to adjust our injection chemistry to negate tungstate precipitaiton. Our ongoing research has resulted in a deeper understanding of the biogeochemical processes underlying biosouring and allowed for the development of novel treatment strategies.