P.9 Biological Oxidation of Sulfides in Oilfield Brines

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Abstract

The presence of sulfides in reservoirs and produced fluids is a function of microbial, electrochemical, and geochemical processes. Problems presented by sulfides include environmental compliance, toxicity, corrosion, reduced well performance, offensive odor, reduced monetary value of products, and increased operating costs. Technologies for the removal and control of sulfides include the use of biocides, scavenging agents, corrosion inhibitors, Claus reactors, amine plants, etc. Problems with these technologies include: ineffectiveness, use of toxic chemicals, cost, and generation of toxic wastes requiring disposal.

To overcome some of these problems, biocontrol strategies (generally termed biocatalysis) are being developed that rely on bacteria that oxidize sulfides in the presence of oxygen or nitrates to produce elemental sulfur or sulfate. In addition, these bacteria can out-complete Sulfate Reducing Bacteria (SRB) for nutrients needed for generation of sulfides thereby controlling further sulfide production. These biocatalytic processes have the advantages of being less costly and more acceptable since they utilize inexpensive, non-hazardous chemicals and generate low toxicity products.

We are developing and plan to demonstrate biocatalysis of sulfides in bioreactors integrated into production infrastructure. Specific objectives are to optimize the growth and sulfide scavenging capacity of a proven nitrate-reducing, sulfide oxidizing consortium of microorganisms and develop appropriate bioreactor platforms for scale design and technology demonstrations.

Biocatalytic processes rely on the ability of sulfide-oxidizing bacteria to remove sulfides while utilizing inexpensive, non-hazardous chemicals that result in the generation of low toxicity products. Most known sulfide biocatalysts require oxygen which in many cases is undesirable. However, a few sulfide-oxidizing biocatalysts such as *Thiobacillus denitrificans* use nitrate as an oxidant under anoxic conditions. Unfortunately, sulfide oxidation by *Thiobacillus* forms sulfate which can be inhibitory to further sulfide oxidation, is difficult to remove from the process stream, and readily reduced back to sulfide by SRB.

The novel biocatalyst system we propose oxidizes sulfide to elemental sulfur using nitrate as an oxidant. This results in less energy consumed per mole of sulfide removed and the production of an insoluble end product, sulfur, that can be removed and sold. Other by-products include biomass and a small amount of nitrogen gas. Furthermore these novel sulfide oxidizing bacteria have simple nutritional requirements for growth and can potentially out-compete SRB for trace nutrients needed for generation of sulfides thereby controlling further biogenic sulfide production.

The INEEL and Phillips Petroleum Company recently performed a successful in-situ proof-of-principle field trial (Coleville Field, Saskatchewan Canada) of sulfide removal by manipulating an indigenous population of nitrate-reducing, sulfide-oxidizing bacteria. A 19 well field-pilot of sulfide removal from produced oilfield brines by sulfide-oxidizing, nitrate-reducing bacteria is reported. Over a period of 50 days, ammonium nitrate (400 mg/L) and monosodium phosphate (12 mg/L) were co-injected upstream of two injection wells flowing 1,412 and 283 barrels (bbl) of water per day. Within 10 days of injection, sulfide levels at the injectors were reduced by 42 to 100% while sulfide levels at producers declined by as much as 50 to 60%. Sulfide oxidation rates greater than 373 mg/L/hr were calculated. These reductions in sulfide were accompanied by increases in the sulfide-oxidizing bacteria at both injectors and producers while slight reductions in sulfate-reducing bacteria were noted. The organisms responsible for the sulfide reduction are indigenous to the Coleville Operations Unit, Saskatchewan, Canada and incompletely oxidized sulfide to elemental sulfur in produced brine under the laboratory conditions tested. The major metabolic end products are elemental sulfur and nitrogen gas. The organisms have been isolated from the field and are being evaluated as potential biocatalysts for sulfide mitigation.

If successful, this technology will mitigate air and liquid sulfide effluents originating in aqueous field output, reduce corrosion facilitated by sulfides, reduce sulfide concentrations in produced fluids, and reduce the toxicity of produced water. Additionally, it has the potential to minimize the application of biocides and corrosion inhibitors.

The goal is to develop technology for application in existing water handling infrastructure. Application of technology is not dependent on the mechanism of sulfide formation (microbial, electrochemical, or geochemical). Potentially this technology can also be used to remove H_2S from gas streams.

Additional information on this project can be found in "Sulfide Removal in Reservoir Brine by Indigenous Bacteria," G. E. Jenneman, P. D. Moffitt, G. A. Bala, and R. H. Webb. 1999. SPE Prod. and Facilities 14 (3):219-225.