

Modeling of Reservoir Souring

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Introduction:

As reservoirs age and water injection is implemented for pressure maintenance, there is an inherent risk of reservoir souring due to the co-mingling of injection waters and formation waters. Souring occurs as a result of the down hole activity by a specialized group of micro-organisms, the sulphate -reducing bacteria (SRB).

The prediction of reservoir souring requires assessment of three key factors:

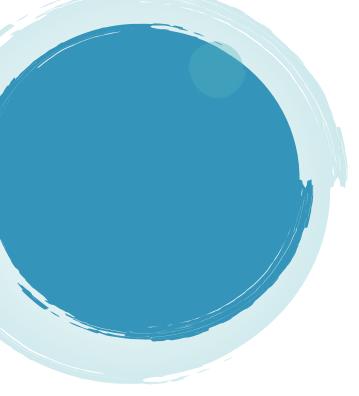
- Microbial generation of H 2S
- Transport and scavenging of microbial generated H 2S in the reservoir
- Partitioning of H 2S between the oil, gas and water phases.

Generic computer-based predictive models currently exist which, although based on the same fundamental principles, take different approaches to assessing the level of H 2S generation. Each model has its own strengths and weaknesses.

Course Outline:

Chapter 1: Introduction

- 1.1 Reservoir Souring
- 2.1 Microbial Reservoir Souring
- 2.1.1 Sulfate-Reducing Bacteria
- 2.1.2 Souring Mechanism
- 2.1.3 H 2 S Transport
- 2.2 Reservoir Souring Remediation Methods

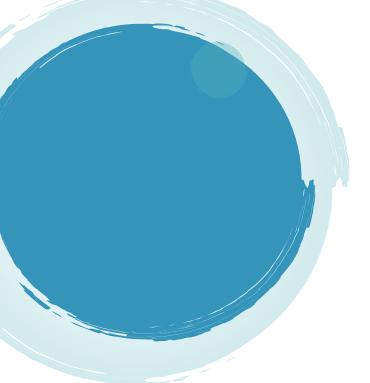


- 2.3.2. Biofilm Model
- 2.3.3 Thermal Viability Shell (TVS) Model
- 2.3.4 Mechanistic Model of Burger et al. (2005
- 2.3.5 Reservoir Souring Simulators
- 2.3.6 Reservoir Souring Simulation with UTCHEM

Chapter 3: General Purpose Adaptive Simulator (GPAS)

- 3.1 Overview of GPAS
- 3.2 Framework
- 3.3 EOS Compositional Module
- 3.4 Chemical Compositional Module
- 3.4.1 Governing Equations
- 3.4.1.1 Material Balance Equations
- 3.4.1.2 Volume Constraint Equation

- 2.2.1 Sulfate Nano-Filtration
- 2.2.2 Biocides
- 2.2.3 Nitrate Injection
- 2.2.3.1 Experiments for Reservoir Souring Remediation by Nitrate.
- 2.2.3.2 Field Application of Nitrate Injection
- 2.3 Modeling of Reservoir Souring
- 2.3.1 Mixing Model



- 3.4.2 Fully-Implicit Solution Procedure
- 3.5 Corner Point Formulation
- 3.6 Parallel Processing

Chapter 4: Implementation of the Biological Model in GPAS

- 4.1 Overview of Biological Model
- 4.1.1 Product Generation, Nutrition, and Inhibition Effects
- 4.1.2 Solving the Biological Model Equations
- 4.2 Modeling Nitrate Inhibition Mechanisms
- 4.2.1 Inhibitory Action of Nitrite
- 4.2.2 Bio-Competitive Exclusion
- 4.2.3 Nitrate Utilization by SRB
- 4.2.4 Nitrate-Reducing Sulfide-Oxidizing Bacteria Stimulation
- 4.3 Implementation in GPAS
- 4.3.1 Solution of the Combined Transport and Biological Equations.
- 4.3.2 GPAS Biological Model Code

Chapter 5: Model Verification with Experimental Data

- 5.1 Microbial Souring in Porous Media
- 5.2 Control of Microbial Souring by Nitrate
- 5.3 NR-SOB Activity in a Batch Reactor



5.4 NR-SOB Activity in a Column

Chapter 6: Effect of Dispersion on Reservoir Souring

- 6.1 Dispersion in Porous Media
- 6.1.1 Molecular Diffusion and Mechanical Dispersion
- 6.1.2 Convection Diffusion Equation (CDE)
- 6.2 Investigation of Dispersion Effects by UTCHEM
- 6.2.1 One-Dimensional Homogeneous Reservoir
- 6.2.2 Three-Dimensional Heterogeneous Reservoir Model
- 6.2.2.1 Seawater Injection (SWI)
- 6.2.2.2 Produced Water Re-Injection (PWRI)
- 6.2.2.3 Effect of Heterogeneity

Chapter 7: Physical Dispersion Model in GPAS

- 7.1 Full Tensor Formulation in GPAS
- 7.2 Semi-Implicit Implementation
- 7.3 Physical Dispersion Model Verification
- 7.3.1 Validation with One-Dimensional Analytical Solution
- 7.3.2 Comparison of Two-Dimensional Simulations with UTCHEM.
- 7.3.3 Non-Orthogonal Grid
- 7.4 Investigation of Numerical Dispersion in GPAS
- 7.4.1 Truncation Error Analysis

- 8.1.3 Initial Nitrate Injection
 - 8.2 Parallel Processing
 - 8.2.1 Model
 - 8.2.3 Multi-Processor Runs
 - 8.2.4 Grid Refinement

- 7.4.2 Gridblock Size Effect
- 7.4.3 Time Step Effect

Chapter 8: Field Application of GPAS Reservoir Souring Model

- 8.1 Non-Orthogonal Reservoir Model
- 8.1.1 Souring without Nitrate Injection
- 8.1.2 Nitrate Injection after H 2 S Breakthrough