MIC: Assessment, Approaches, and Challenges

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MIC Assessment: Root Cause Analysis

- What Happened?
- Gather Data
- Identify Causal Factors
- Identify Root Cause
- Recommendations and Solutions

Gather Data

Chemical

Water, oil and gas composition; T and P; pH; solids composition

Microbiological

Microbial concentrations and types (sessile vs. planktonic); nutrients and biometabolites; oxygen

Metallurgical

Composition; corrosion products; pit orientation and morphology; welds; inclusions; internal vs. external; failure analyses

Operational

Process flow; velocity; stop/start; drilling, completion and production chemicals; corrosion and failure rates; pigging; inspection data; hydrotest; emulsions; temperature changes; water cuts;

MIC Assessment Questions

Chemical
- Are environmental conditions such that abiotic mechanism could explain observed rates?

Microbiological
- Are environmental conditions conducive to microbial growth and metabolism?

Metallurgical
- Are corrosion products and features characteristic of MIC present?

Operational
- Have changes occurred that may enhance the activity of microorganisms?

Identify Causal Factors*

- Immediate or direct cause (CO_2; H_2S; O_2; MIC)
- Identify conditions not central to main problem (i.e., contributing conditions)
  - Sequence of events leading to the problem (timeline)
  - What conditions allow the problem to exist
    - Cause and effect diagrams
- Root cause determines why preventative systems/management systems in place did not mitigate the incident.

* R.B. Eckert. 2016. Internal Corrosion Failures: Are We Learning from the Past? Materials Performance 55 (11):64-68.

Recommendations and Solutions

- Identification and recognition of all causal factors
- Plans to mitigate and prevent future incidents
- Lessons learned and best practices identified

Challenges – Preservation of Coupon/pipe cut outs for Chemical/metallurgical Analyses

Anaerobic Jars

coupons and solids (pig returns/envelopes)

End caps and/or Saran Wrap

pipe cut outs

Do NOT CLEAN PIPE prior to shipping!

Mark flow direction and orientation on outside of pipe.

Indicate leaks on outside

Composite samples near and distal to corrosion

Ship expeditiously; Do not allow to dry

Field testing

Challenges – Collection and Preservation of Samples for Microbiological Analyses

Culture based testing [1]

Ineffective for old and dried out samples

Storage at $4^{o}C$ yield best results for SRB enumeration.

- One day storage at $4^{o}C$ can result in underestimates of 10%
- Storage at higher temperatures yield values 100 times higher.

[1]Kilbane, J.J., Monitoring Pipelines for MIC. Materials Performance 53:68-71.2014.

Molecular based testing [2]

DNA can be detected in both living and dead cells

Sample preservation and primer sets for sequencing most critical steps

- Filtration + DNAzol or dried vs. No filtration + ice

Commercial labs – ice vs. chemical preservatives

[2]De Paulo, R. et al. DNA Sequencing of Oilfield Samples: impact of protocol choices on the microbiological conclusions, Paper 11662, NACE Corrosion 2018.

Challenges – Interpretation of Results

- Concentrations (planktonics vs. sessile)
  - cATP, culture based, qPCR, AquaQuant, PhosphoLipid, Acridine Orange Direct Counts
- Omics
  - Genomics: 16S vs. shot gun sequencing (metagenomics)
  - Transcriptomics
  - Proteomics
  - Metabolomics
    - biometabolites
- Corrosion products
  - Oxygen vs. anoxic samples
- Pit morphology and metallurgical features
- Water chemistry
  - Analysis procedures
- Identification of a geochemical or biochemical markers unique to MIC.

Challenges – Cost Justification

- Value in the right answer
  - Cost of using wrong chemical and mitigation
  - Lost time in implementing correct remedial activities
    - Further corrosion and failures
    - Unplanned Shut downs – deferred or lost production
  - Environmental damage – fines and litigation
  - Damaged reputation – loss of license to operate
  - Injuries and fatalities