February 19, 2020

OTD Underground Storage Collaborative: Industry Needs

Kristine Wiley and Amanda Harmon, GTI
Daniel Ersoy, Element Resources

WWW.OTD-CO.ORG

OTD

Operations Technology Development

Operations Technology Development (OTD) Overview

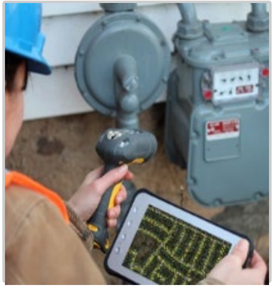
Established 2003

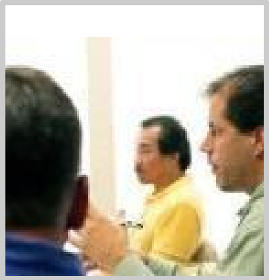
Stand-alone, not-for-profit, member-controlled company where gas utilities work together to develop technology solutions to common issues

27 Members

- Annual membership dues are calculated based on number of customer meters
- New projects selected by members based on needs
- Each member votes their own dollars to specific projects
- All members have access to all project information

$12M annual dues	**$150-$750k** member/yr	**$0.50** meter/yr





OTD Members

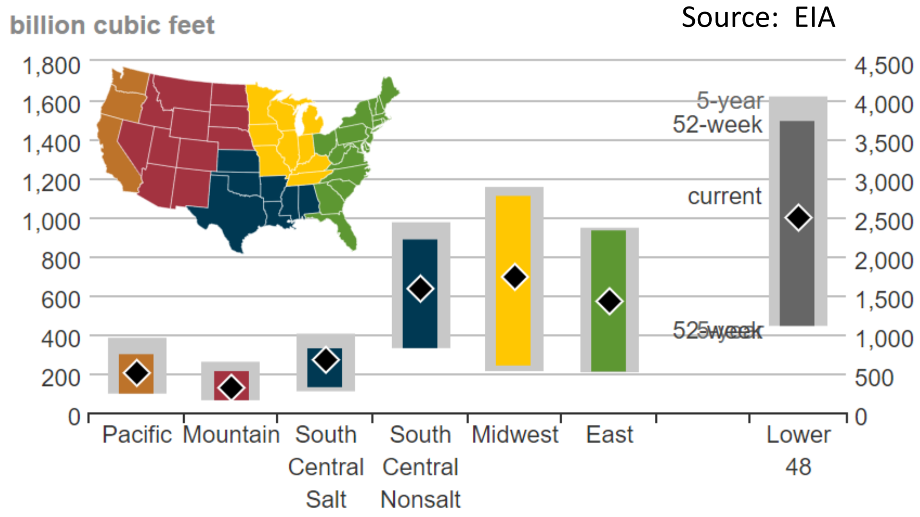
Serving 50 million gas consumers in the US and Canada

OTD Operations Technology Development

Research Foundation
Southern California Gas Company – A Sempra Energy utility
Pacific Gas and Electric Company (PG&E)
Atmos energy
Southwest Gas
Ameren – Focused Energy. For life.
conEdison
CenterPoint Energy
Entergy
Peoples Gas – Natural Gas Delivery
Intermountain Gas Company – A Subsidiary of MDU Resources Group, Inc.
NYSEG
RG&E
National Fuel
Avista
NiSource
NW Natural – We grew up here.
PSNC Energy – A SCANA Company
Oklahoma Natural Gas – A Division of ONE Gas
Enbridge
Washington Gas – A WGL Company
Dominion Energy
Nicor Gas
TECO Peoples Gas
Duke Energy
spire
nationalgrid
Liberty Utilities
Black Hills Energy

Underground Natural Gas Storage Collaborative - Background

> Develop a collaborative of underground natural gas storage operators to identify and facilitate research needs and projects related to underground natural gas storage operations



> Limited funding sources for underground natural gas storage R&D

> Approximately half of OTD member companies have underground storage assets

Underground Natural Gas Storage Collaborative - Overview

- Collected approximately 30 needs
  - One-on-one and roundtable discussions with operator subject matter experts (SME) and UGS research and consulting organizations
- Medium to high priority needs were grouped into 16 programs
- Developed a draft research roadmap
  - Program areas
  - Timeline
  - Stakeholders
  - Project type

Underground Natural Gas Storage Collaborative - Needs

OTD Operations Technology Development

- Double Barrier Requirement
  - Develop new/better technology
  - Determine impact of taking certain actions and a way to quantify and qualify the consequences of imposing such a requirement
- Annular Space Pressure
  - Direct pressure measurement
  - Risk based maximizing of annulus and aboveground gas measurements
- Gas Leak Guidance
  - Levels, locations, leak rates, measurement methods
- Cycling Affect on Cement Life
  - Collaborative research with DOE and PHMSA

DRAFT UNDERGROUND GAS STORAGE RESEARCH ROADMAP

#	Priority	UGS Research Program	Research Class: Technology	Research Class: Knowledge	Research Class: Standards	Research Class: Regulations	Timing: 2020	Timing: 2021	Timing: 2022	Timing: 2023	Timing: 2024	Sponsors / Stakeholders: Government	Sponsors / Stakeholders: Operaor	Sponsors / Stakeholders: Trade	Sponsors / Stakeholders: Committee
1	Very High	**Double Barrier Requirements**	T	K								G	O	T	
2	High	**Regulator and Standard Resources and Data**		K	S	R						G	O	T	C
3	High	**Annular Space Pressure**	T	K									O	T	C
4	High	**Gas Leak Guidance**		K									O	T	C
5	High	**Inventory Methods, Models, and Procedures**		K									O		
6	High	**Cycling Affect on Cement Life**		K								G	O		
7	High	**Well Pad Size and Protection**		K									O		
8	High	**Through Tubing/Patch Casing Inspection**	T									G	O		
9	Medium	**Risk Guidance**		K	S	R						G	O	T	C
10	Medium	**Buffer Zone Practices**		K	S								O		C
11	Medium	**Valve Testing**	T									G	O		
12	Medium	**Blow-out Guidelines**		K		R							O		C
13	Medium	**Pressure and Flow/Velocity Measurement and Guides**	T										O	T	C
14	Medium	**Gas Quality Real Time**	T										O	T	
15	Medium	**Emission Reduction Quantification**		K		R							O		
16	Medium	**Decommissioning Process**		K	S	R							O		C

MIC in Underground Natural Gas Storage Formations - Background

OTD Operations Technology Development

- **Purpose:** To create a preliminary guidance document for assessing microbiological influenced corrosion (MIC) and biological gas souring in underground storage formations

- **Background:** MIC is a known risk that can have deleterious effects on energy infrastructure
- MIC is estimated to contribute up to 20% of all corrosion damage of metals and building materials and 40% of overall corrosion costs
- API 1170 and 1171 to ensure integrity of underground storage assets
- Blade's RCA for Aliso Canyon determined that MIC caused integrity loss of well tubing

Microbiological Community in Underground Storage Formations - Scope

- **Scope of Work:** Sample gas and liquids during injection and withdrawal period from underground storage formations.
- The storage formations samplers were depleted natural gas and aquifers in the Midwest.
- Chemical and molecular biological analysis of samples

Image: Sampling point at underground natural gas storage well head (GTI)

Microbiological Community in Underground Storage Formations - Results

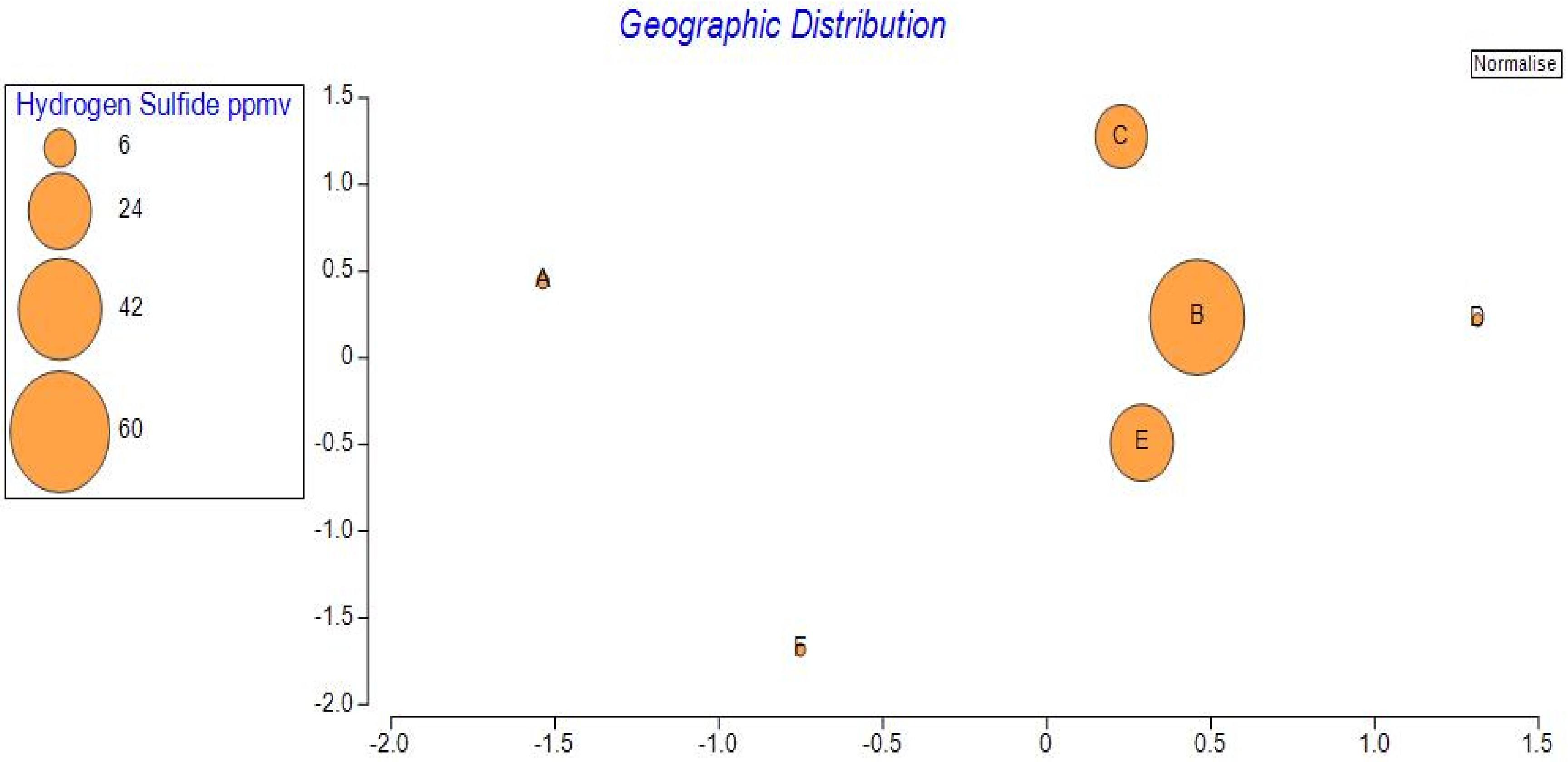


Figure 1: Geographic distribution of five sampling sites (A-E) based on latitude and longitude. Circle size indicates average H_2S concentrations. Orientation may be obscured to preserve sample site anonymity.

Microbiological Community in Underground Storage Formations - Results

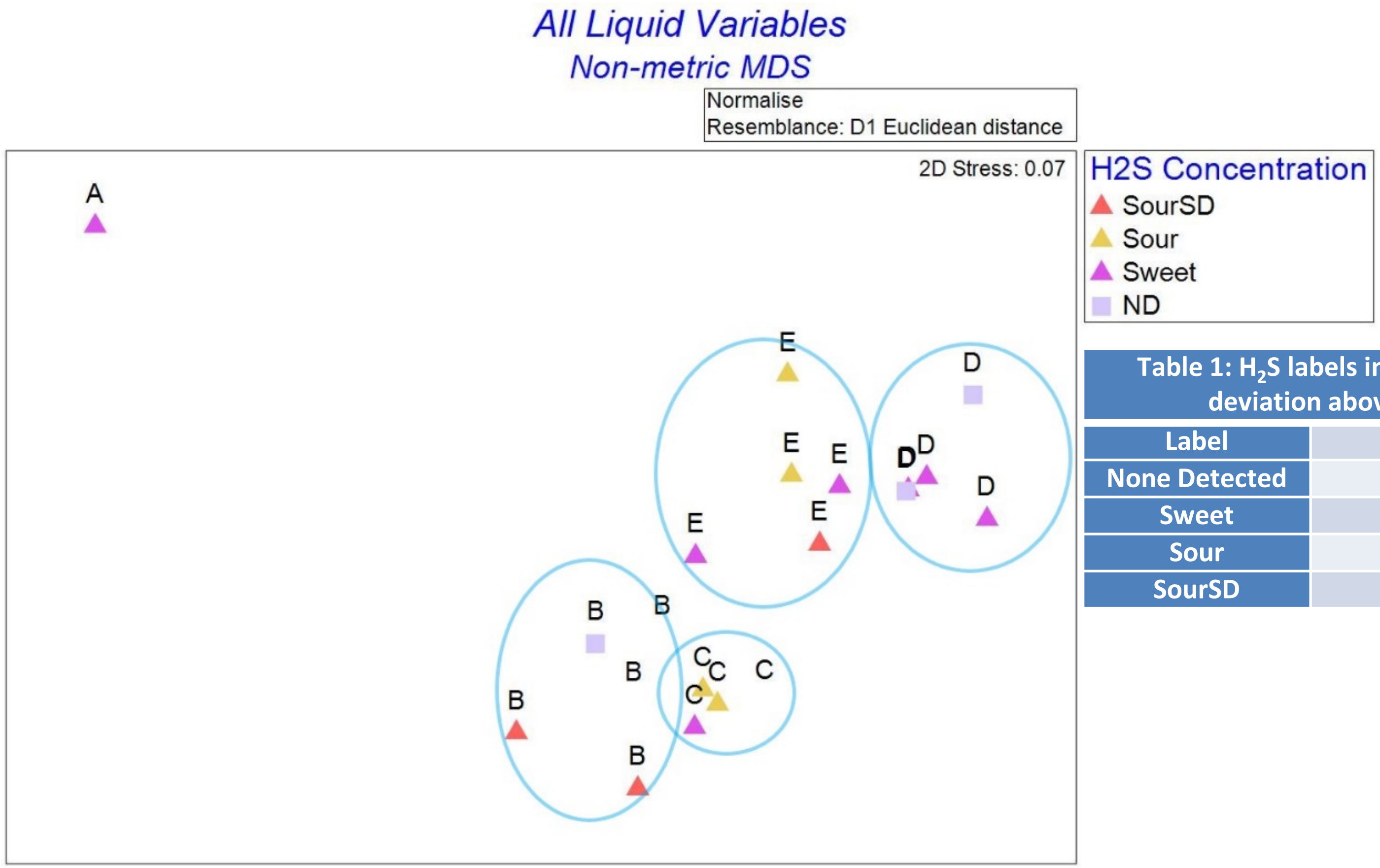


Table 1: H_2S labels in graphs. *= one standard deviation above average sampled	
Label	Value
None Detected	No H_2S present
Sweet	x< 4.0 ppm, x>0
Sour	x≥ 4.0 ppm, x<31 ppm*
SourSD	x≥31ppm*

Figure 2: Non-Metric MDS Euclidian Distance plot of all liquid samples. Symbols represent H2S concentration. Labels represent sample site. Well site groups are circled. All 36 variables analyzed are weighted equally.

Microbiological Community in Underground Storage Formations - Results

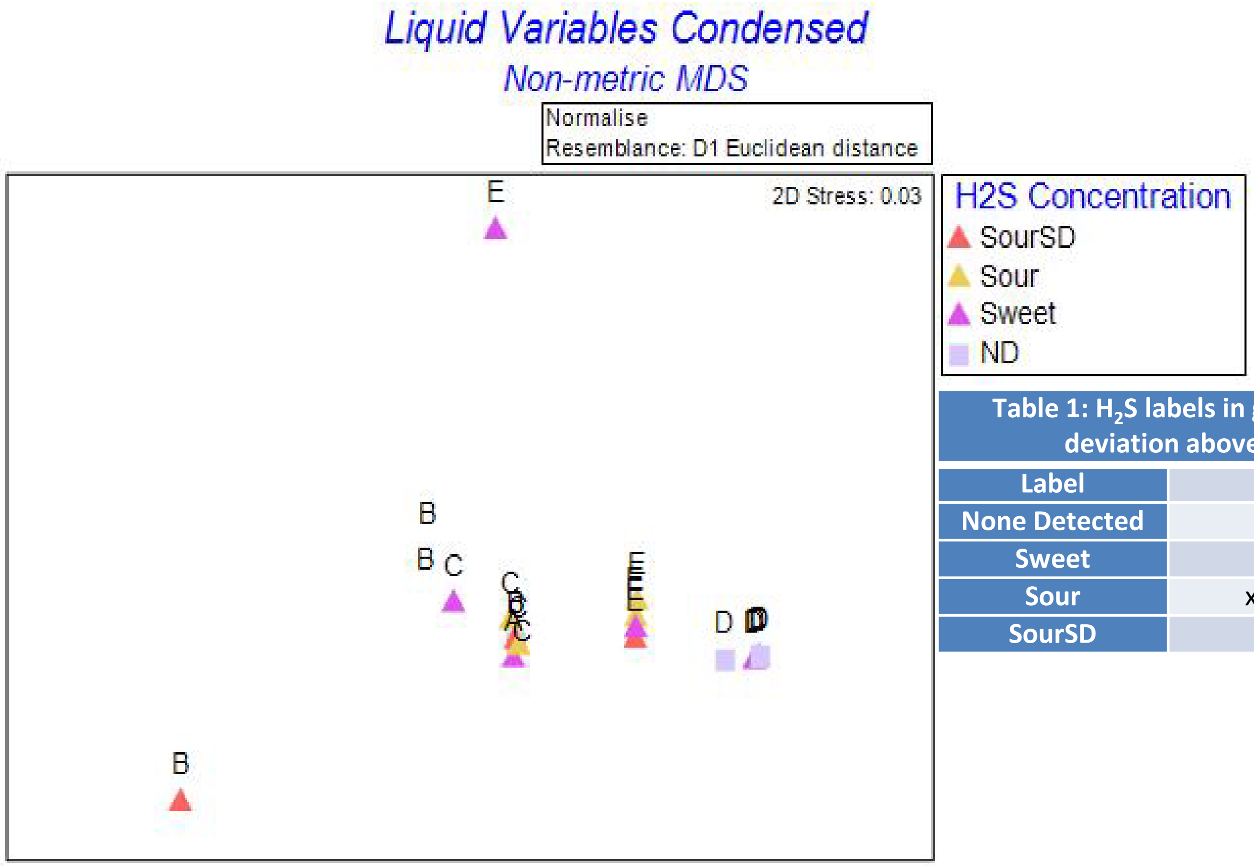


Table 1: H_2S labels in graphs. *= one standard deviation above average sampled	
Label	Value
None Detected	No H_2S present
Sweet	x< 4.0 ppm, x>0
Sour	x≥ 4.0 ppm, x<31 ppm*
SourSD	x≥31ppm*

Figure 3: Non-Metric MDS Euclidian Distance plot of all liquid samples. Symbols represent H2S concentration. Labels represent sample site. Only 5 variables associated with promoting sulfur microorganisms are analyzed and all weighted equally.

Microbiological Community in Underground Storage Formations - Results

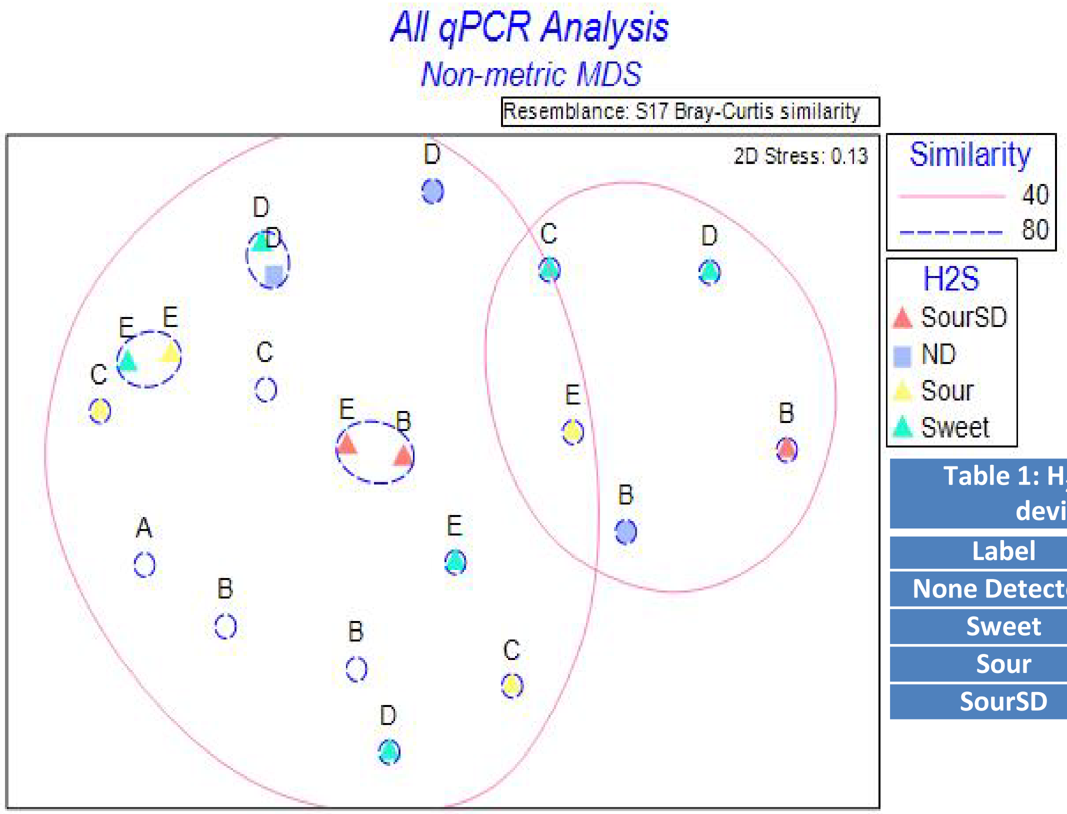


Table 1: H_2S labels in graphs. *= one standard deviation above average sampled	
Label	Value
None Detected	No H_2S present
Sweet	x< 4.0 ppm, x>0
Sour	x≥ 4.0 ppm, x<31 ppm*
SourSD	x≥31ppm*

Figure 4: Non-Metric MDS Bray Curtis Distance plot of all microbiology samples. Symbols represent H2S concentrations, samples without a symbol reflect locations where microbiology was sampled without a gas analysis. Labels represent sample site. All variables are transformed by LOG10 and weighted equally. Blue circles indicate 80% similarity and gray lines depict 40% similarity.

Microbiological Community in Underground Storage Formations - Results

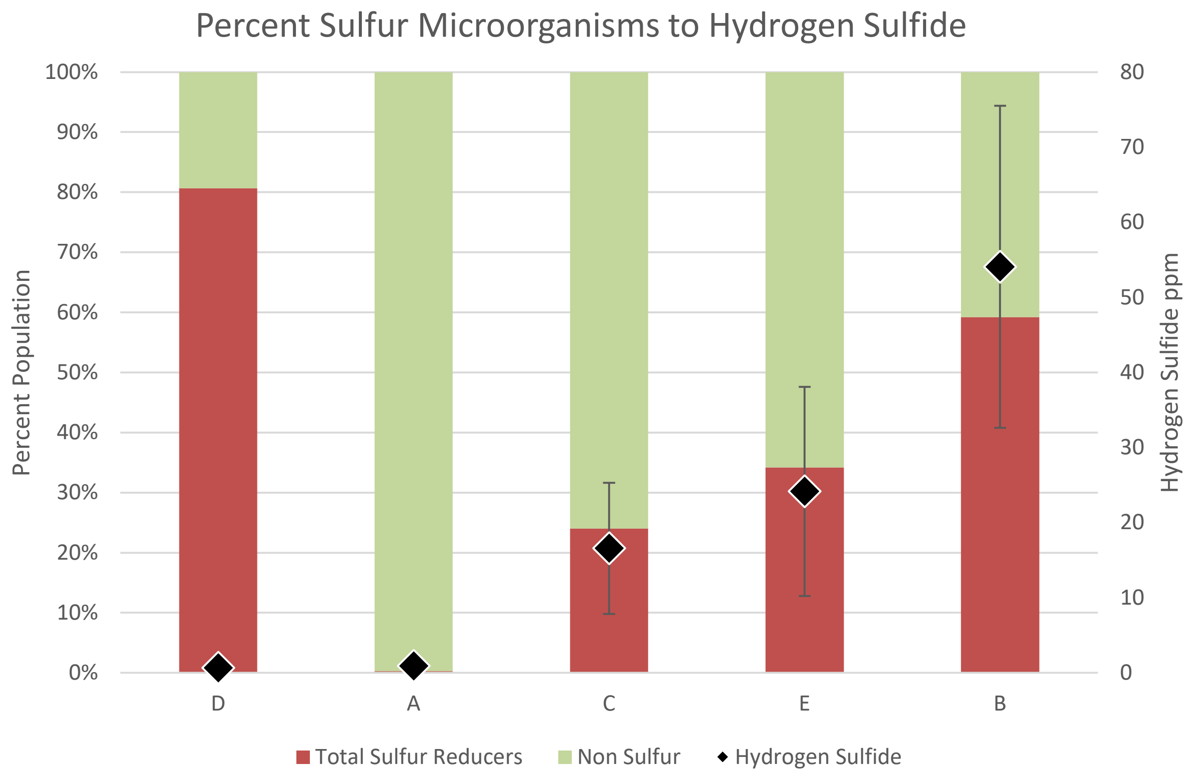


Figure 5: Relative Abundance of Sulfur Microorganisms to Hydrogen Sulfide

Microbiological Community in Underground Storage Formations - Results

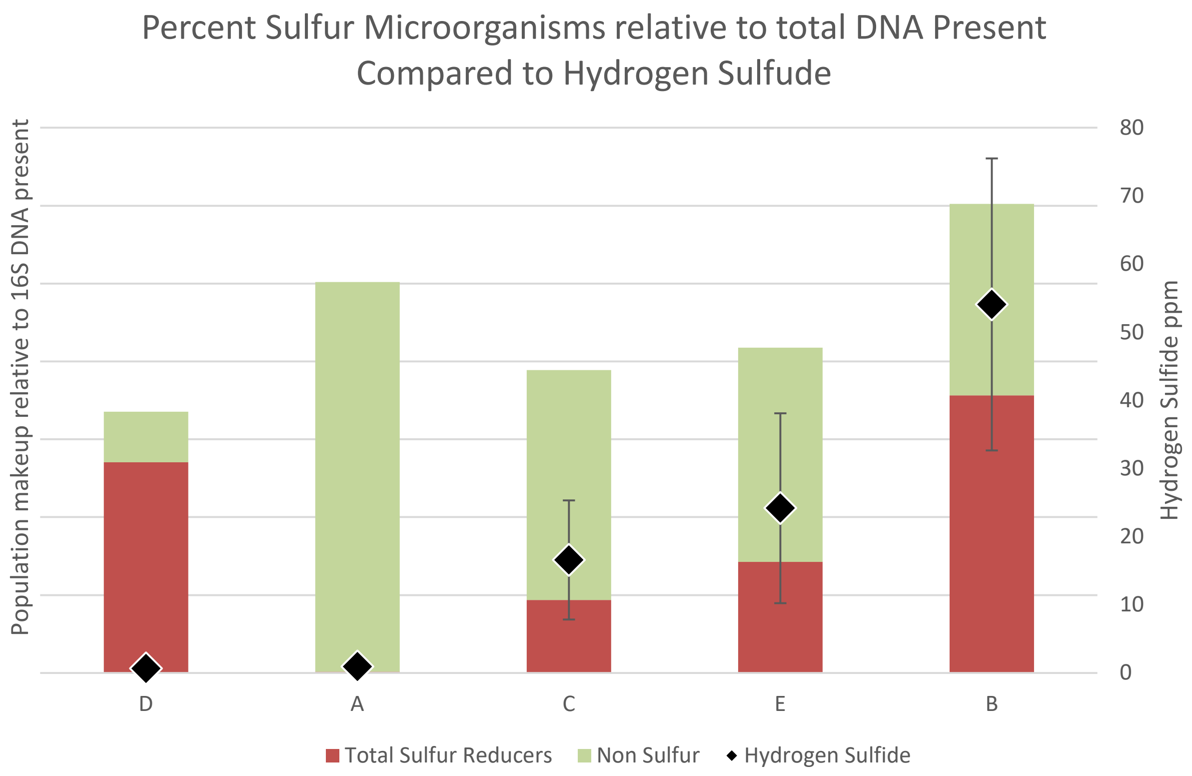


Figure 6: Relative Abundance of Sulfur Microorganisms to total DNA Present Compared to Hydrogen Sulfide

Microbiological Community in Underground Storage Formations - Conclusions

Operations Technology Development

- **Conclusions: More questions than answers!**
- Each storage formation has a unique environmental microbiology community
- MIC associated microorganisms were found in both aquifers and depleted hydrocarbon formation fluids
- H_2S comes from abiotic and biotic pathways
  - Is there a source of contamination?
- Failure analysis of tubing structure indicated MIC pitting in Aliso Canyon
  - Methanogens were determined to be the predominate species

Kristine Wiley

kwiley@gti.energy