SPE · AAPG · SEG CCUS
CARBON CAPTURE, UTILIZATION, AND STORAGE
THE INDUSTRY'S LEADING EVENT FOR CCUS MANAGEMENT AND DEVELOPMENT
3-5 MARCH 2025
HOUSTON, TEXAS

A Quick Way to Evaluate the Effect of CO_2 Impurities on Caprock Performance for Carbon Capture and Storage Projects

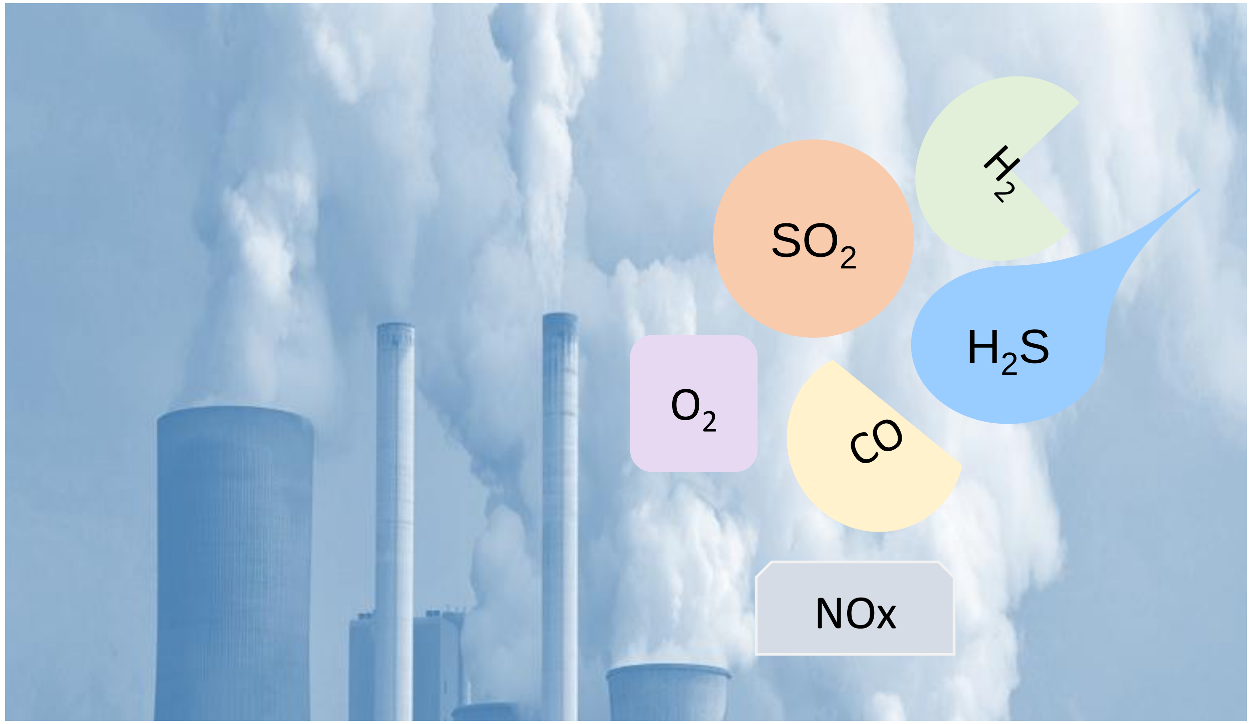
Yani C. Araujo de Itriago, Benjamin Harrell, Guadalupe Herrera

INTERTEK Westport Technology Center, Houston, Texas

intertek Total Quality. Assured.

OUTLINE

- Introduction
- Objective
- Experimental Procedures
- Results and Discussion
- Conclusions



INTRODUCTION

CCS → **one of the** best available technology to reduce carbon emissions from the atmosphere

A major challenge in the implementation of the CCS technology is to meet the CO_2 quality requirements for transportation and injection into the storage site → CO_2 from different sources → Impurities

Negative Impact →

- Cost of CO_2 capture
- Infrastructure used for its transportation
- Performance of the seal and injectivity

IMPORTANT FACTS

- $scCO_2$ + impurities → geochemical reactions → impact the CO_2 plume ↓↑, dissolution of the rock mineral ↑ & mineral precipitation ↓
- Impurities are unavoidable during CCS
- N_2, Ar, O_2, CO, H_2O, H_2S, SOx, NOx, CH_4, H_2
- There is not a global standard for CO_2 specification → project dependent

Project	CO_2 Mol%	H_2O ppm	H_2S ppm	CO ppm	O_2 ppm	CH_4 ppm	N_2 ppm	Ar ppm	H_2 ppm	SO_x ppm	NO_x ppm
Porthos (Porthos 2022)	≥ 95	≤ 70	≤ 5	≤ 750	≤ 40	≤ 10000	≤ 24000	≤ 4000	≤ 7500	≤ 10	≤ 5
Northern Lights (Equinor 2019)		≤ 30	≤ 10	≤ 100	≤ 10	≤ 100			≤ 50	≤ 10	≤ 10
National Grid (Brownsort 2019)	≥ 95	≤ 50	≤ 20	≤ 2000	≤ 10				≤ 2000	≤ 100	≤ 100
Dynamis -Store (De Visser 2008)	≥ 95	≤ 500	≤ 200	≤ 2000	≤ 4000	≤ 4000	≤ 4000	≤ 4000	≤ 4000	≤ 100	≤ 100
Carbon Net (Murungan 2019)	≥ 93.5	100	100	≤ 5000	5	5	5	5	5	200	250
East Cost CO_2 Cluster (ECC 2022)	≥ 96	≤ 50	≤ 5	≤ 100	≤ 10	≤ 4000	≤ 4000	≤ 4000	≤ 750	≤ 20	≤ 10

OBJECTIVE

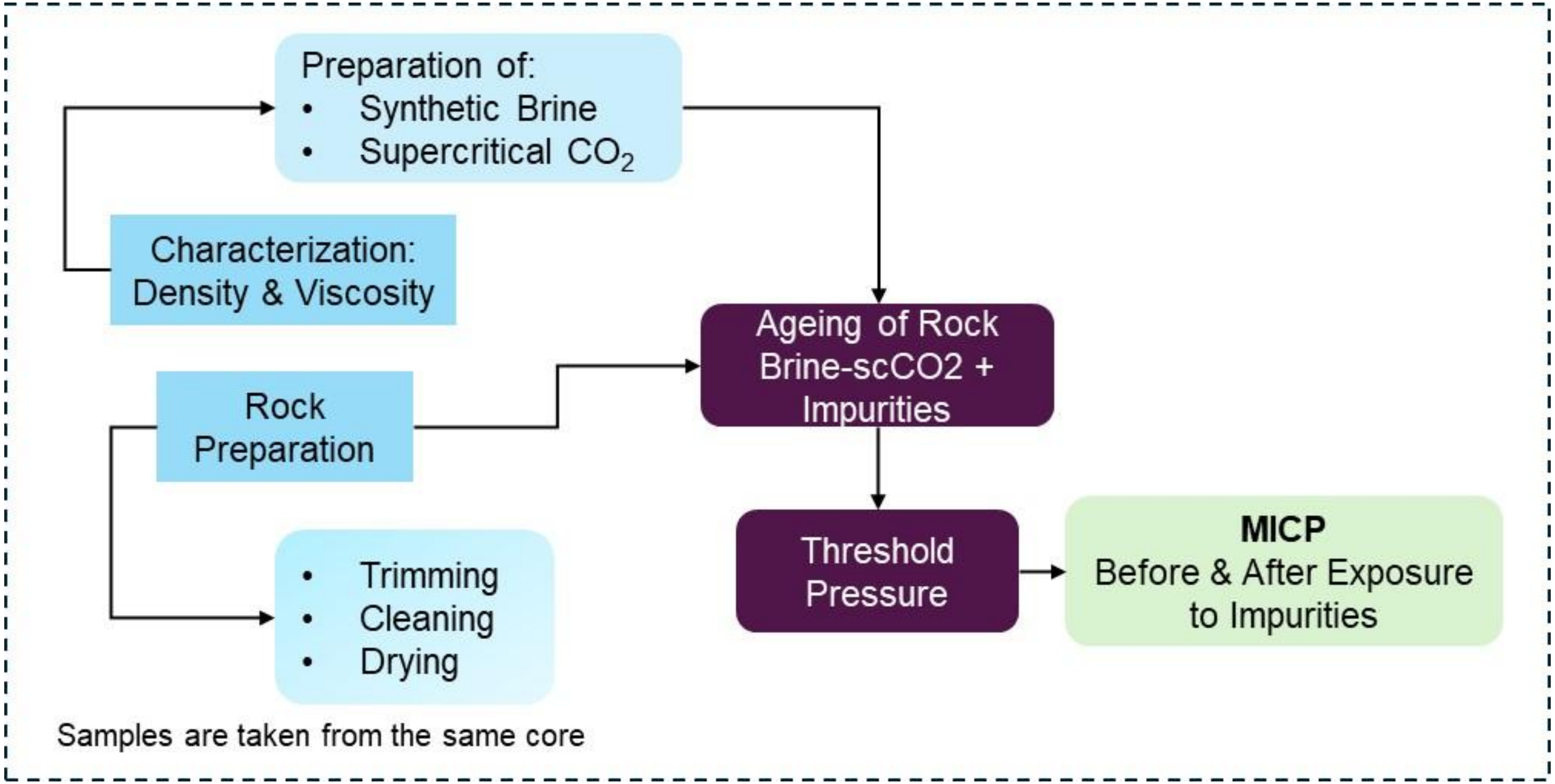
- CO_2 co-injected with impurities → costs reductions
- Effect of the impurities in the process performance must be evaluated
- **Geological Storage** → impurities can significantly affect key properties of the seal & reservoir rock

↓

- Injection pressure must be > threshold pressure of storage formation, but < threshold pressure of the caprock
- The threshold pressure → caprock seal capacity

This study was performed with the aim to establish a quick procedure to evaluate the effect of the impurities commonly present in the CO_2 stream in the threshold pressure

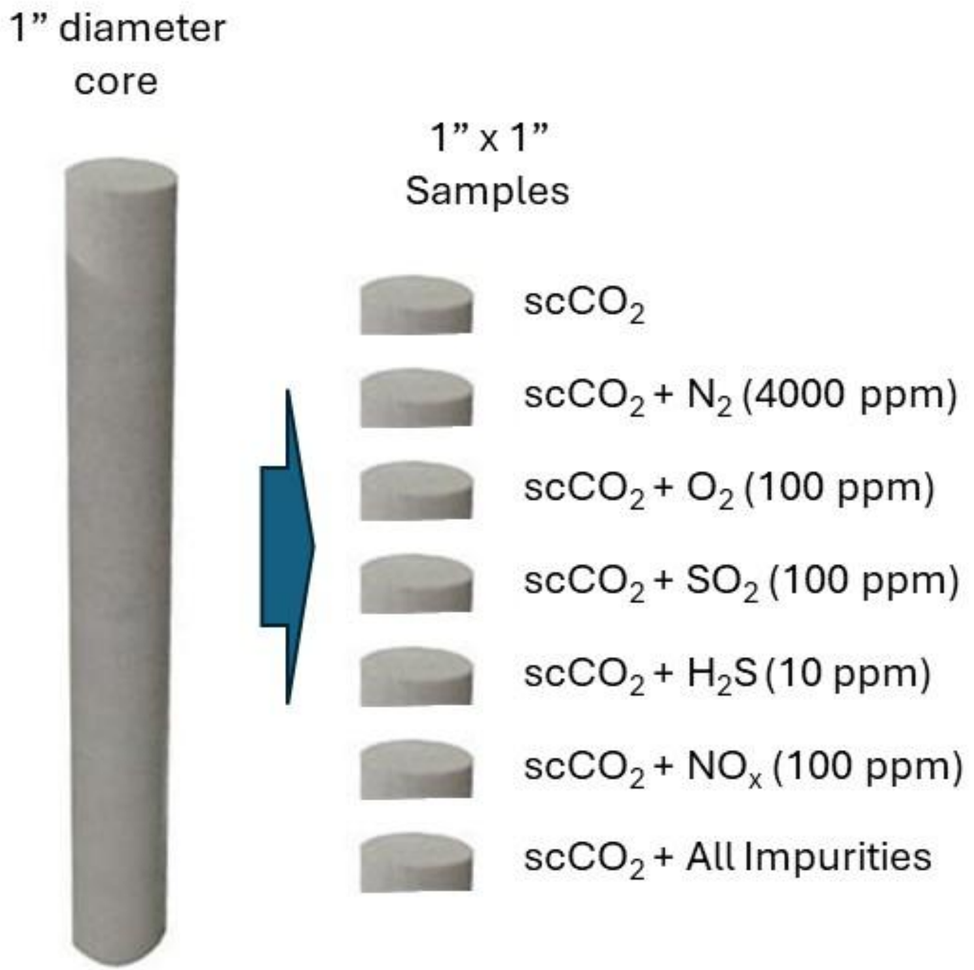
EXPERIMENTAL METHODS: WORKFLOW

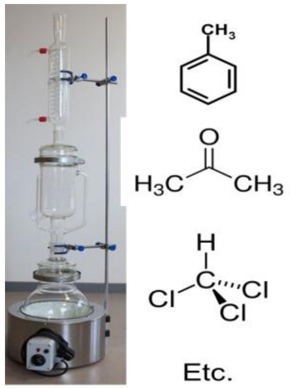


EXPERIMENTAL METHODS: ROCK PREPARATION

3 Set of Samples

- ✓ Sandstone
- ✓ Carbonate
- ✓ Shale





Cleaning
Solvent selected by lithology

Drying

A Quick Way to Evaluate the Effect of CO_2 Impurities on Caprock Performance for Carbon Capture and Storage Projects. **Araujo et al.**

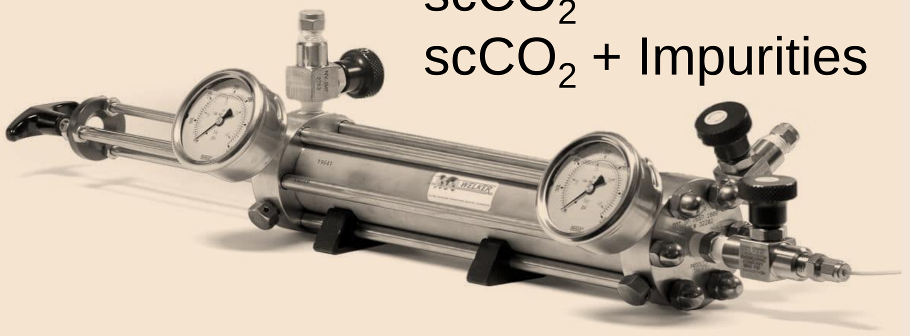
EXPERIMENTAL METHODS: FLUIDS

Fluids
- Synthetic Brine
- Supercritical CO_2

Fluids Characterization
- ✓ Composition, pH
- ✓ Density
- ✓ IFT
- ✓ GC-FID
- ✓ GC-TCD

Brine

Rock Lithology	Temperature (°F)	Pressure (psi)
Sandstone	175	3300
Shale	160	3350
Carbonate	180	3550



$scCO_2$
$scCO_2$ + Impurities

N_2	(4000 ppm)
O_2	(100 ppm)
SO_2	(100 ppm)
H_2S	(20 ppm)
NO_x	(100 ppm)
Mixture	

EXPERIMENTAL METHODS: STATIC AGEING & MICP

- Static tests → effect of CO_2 in the rock-fluid system during long-time storage
- Sealing performance of the storage rock and caprock → Threshold Pressure

Rock Placed in Pressure Cell

Cell Filled with Brine + (scCO + Impurities Mixture)

Ageing for 21 days at $(T, P)_{res}$

Mercury Injection Capillary Pressure (MICP)

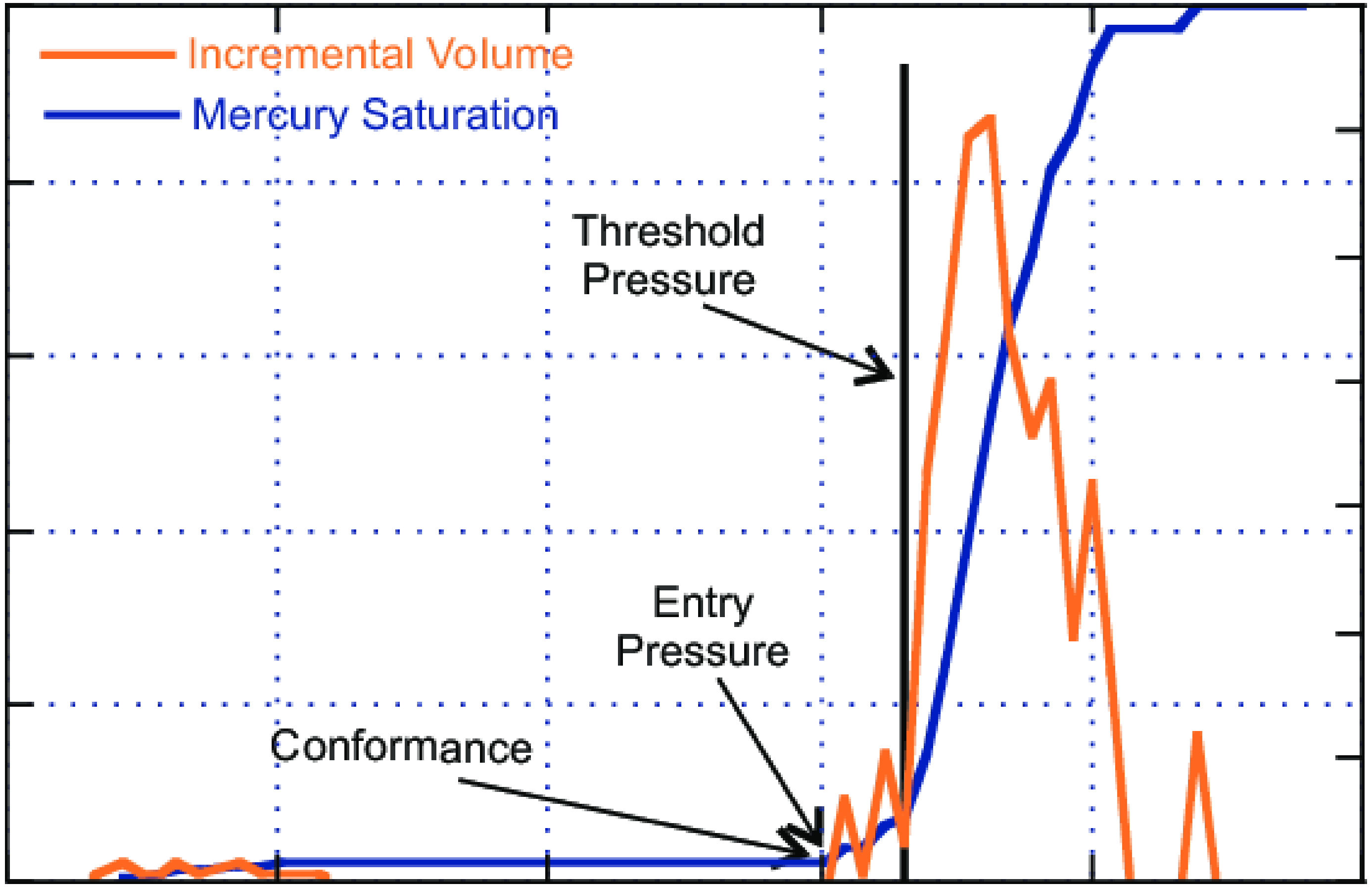
Threshold Pressure

Micromeritics Autopore-IV

EXPERIMENTAL METHODS: MICP

Mercury Injection Capillary Pressure

- **Entry pressure →** pressure at which mercury starts to penetrate the pores of the rock
- **Threshold pressure →** pressure at which a continuous filament of non-wetting phase extends through the pore network of the sample & represents capillary seal breach



Source: Svendsen et al. (2004)

RESULTS & DISCUSSION

Sandstones: Changes in Threshold Pressure

Rock Lithology	Fluid System	Laboratory Threshold Pressure (psi)	IFT (dyne/cm)	Cos (θ)	Reservoir Threshold Pressure* (psi)
Sandstone 1	$scCO_2$ + Brine	2834.25	40.63	0.999	313.37
Sandstone 2	$scCO_2$ + Brine + N_2	2645.98	40.04	0.999	288.13
Sandstone 3	$scCO_2$ + Brine + O_2	2608.23	39.16	0.975	271.07
Sandstone 4	$scCO_2$ + Brine + SO_2	2298.34	25.45	0.906	138.09
Sandstone 5	$scCO_2$ + Brine + NO_x	2132.45	24.53	0.908	129.30
Sandstone 6	$scCO_2$ + Brine + H_2S	2398.93	39.34	0.991	254.57
Sandstone 7	$scCO_2$ + Brine + All	2046.78	23.12	0.906	116.78

*Reservoir Threshold Pressure: Delta Above in-situ Pore Pressure

RESULTS & DISCUSSION

Shales: Changes in Threshold Pressure

Rock Lithology	Fluid System	Laboratory Threshold Pressure (psi)	IFT (dyne/cm)	Cos (θ)	Reservoir Threshold Pressure (psi)
Shale 1	$scCO_2$ + Brine	6521.67	38.95	0.999	691.27
Shale 2	$scCO_2$ + Brine + N_2	6325.43	38.85	0.999	668.32
Shale 3	$scCO_2$ + Brine + O_2	6305.34	30.78	0.835	441.07
Shale 4	$scCO_2$ + Brine + SO_2	6023.56	19.36	0.896	284.65
Shale 5	$scCO_2$ + Brine + NO_x	5876.24	17.09	0.888	242.76
Shale 6	$scCO_2$ + Brine + H_2S	5998.47	24.05	0.891	349.86
Shale 7	$scCO_2$ + Brine + All	5025.87	17.48	0.886	212.02

RESULTS & DISCUSSION

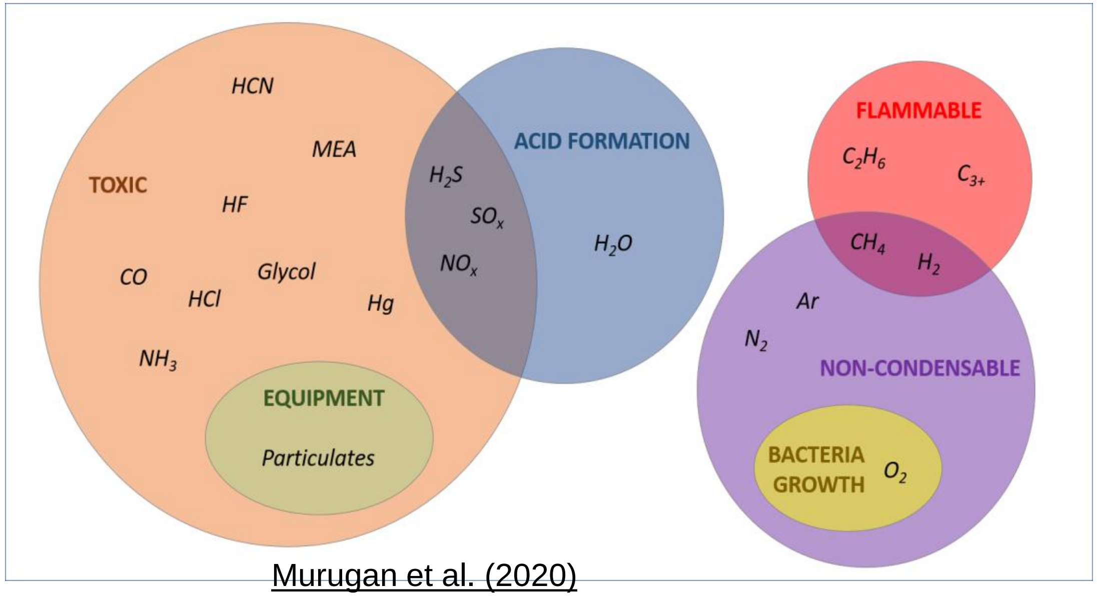
Carbonates: Changes in Threshold Pressure

Rock Lithology	Fluid System	Laboratory Threshold Pressure (psi)	IFT (dyne/cm)	Cos (θ)	Reservoir Threshold Pressure (psi)
Carbonate 1	$scCO_2$ + Brine	1196.34	39.36	0.989	126.86
Carbonate 2	$scCO_2$ + Brine + N_2	1194.67	38.96	0.979	124.05
Carbonate 3	$scCO_2$ + Brine + O_2	1189.57	31.75	0.845	86.86
Carbonate 4	$scCO_2$ + Brine + SO_2	756.35	18.45	0.906	34.44
Carbonate 5	$scCO_2$ + Brine + NO_x	748.27	17.34	0.908	32.07
Carbonate 6	$scCO_2$ + Brine + H_2S	1006.78	36.15	0.921	91.24
Carbonate 7	$scCO_2$ + Brine + All	635.67	19.36	0.896	30.04

RESULTS & DISCUSSION

- When iron species are present in the rock, undesirable reactions can happen in presence of brine + (CO_2 + O_2) → Sulfuric & nitric acid can be formed, and iron sulphates can be produced leading to mineral dissolution and precipitation
- During short-term storage the impact of N_2 and H_2S in the TEP was significantly less compared with the SOx, NOx, and Oxygen impurities; **however**, these impurities could cause major issues if the CO_2 stored is considered for further applications

$$P_{bCO2}=P_{aHg}\frac{\sigma_{bCO2}\cos\theta_{bCO2}}{\sigma_{aHg}\cos\theta_{aHg}}$$



Murugan et al. (2020)
https://doi.org/10.3390/c6040076

CONCLUSIONS

- To determine the threshold pressure, MICP is faster than other methods; however, **results need to be converted to reservoir conditions.**
- High impact of IFT and θ on the threshold pressure and hence on the seal capacity of the caprock. IFT CO_2-brine decreased significantly in presence of SO_2 and NOx contaminants with negative impact in the threshold pressure.
- The impact of the impurities seems to be stronger in shales & carbonates compared to clean sandstones.
- The findings of this study can be used to understand the effect of CO_2 impurities, as part of the requirements established for the safe implementation of the technology.
- The methodology used in this study is recommended for a **quick and low-cost** assessment of the effect of the CO_2 impurities on the caprock and the reservoir rock.

ACKNOWLEDGEMENTS

We’d like to thank INTERTEK Westport Technology Center for the support and encouragement to share the results of this study.

Thank You!

Questions?