A Study of the Effects of Impurities on CO_2 Fluids flowing in Pipelines

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1. Introduction

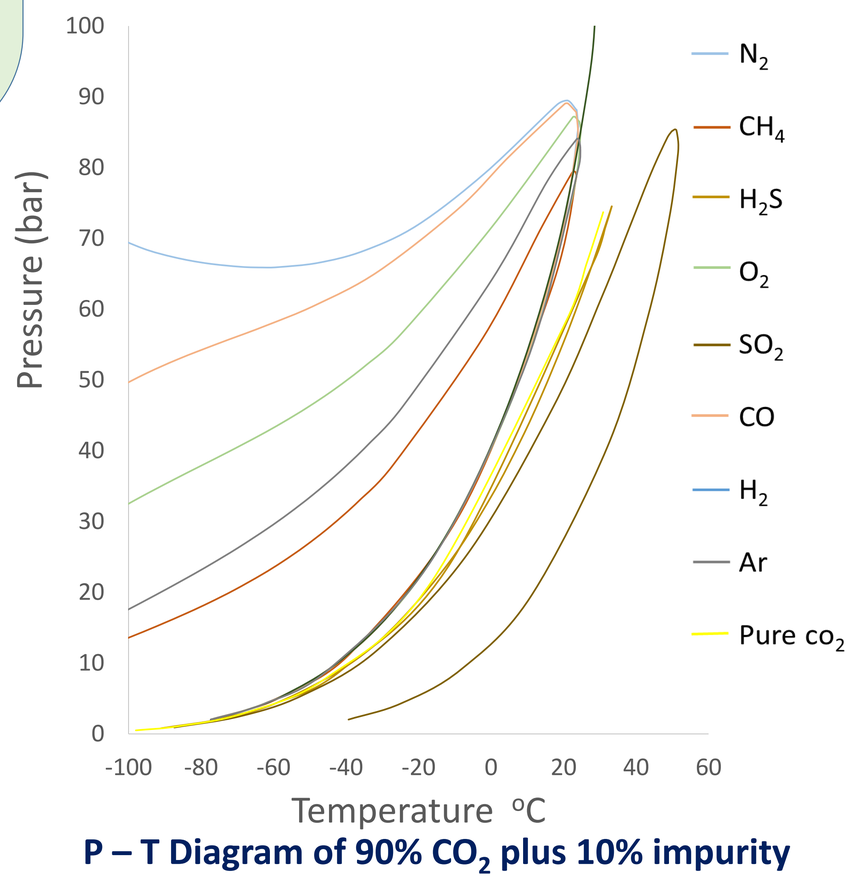
- CO_2 is captured from large emission sources, transported to storage locations and stored in saline aquifers.
- Pipelines are used in the onshore and offshore transportation of CO_2 fluids.
- CO_2 fluids flowing in pipelines contain impurities.[1,2]
- Impurities in CO_2 pipelines include: N_2, CH_4, H_2S, SO_2, H_2, O_2, Ar, H_2O, CO, etc.[1]
- Impurities affect flow behaviour of CO_2 fluids in pipelines.
- Understanding the effect of these impurities will improve the design of CO_2 pipelines.

Bubble and Dew points of 90% CO_2 and 10% impurity at 0 °C

Components	P_b (bar)	P_d (bar)	ΔP_d
$CO_2 + N_2$	80	40	40
$CO_2 + CH_4$	58	40	18
$CO_2 + H_2S$	34.8	33.4	1.4
$CO_2 + SO_2$	30.5	12.7	17.8
$CO_2 + CO$	79	41	38
$CO_2 + O_2$	72	40	32
$CO_2 + H_2$	140	40	100
$CO_2 + Ar$	64	40	24

2. Methodology

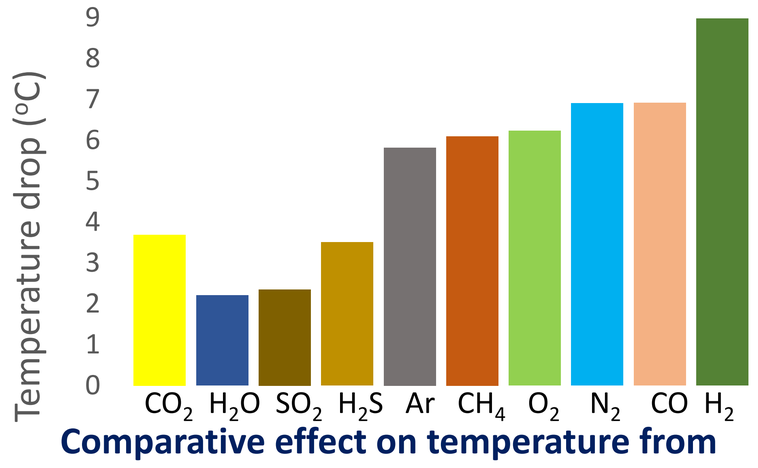
- Aspen HYSYS, gPROMS and HydraFlash are used to simulate
  - Change in pressure,
  - Change in temperature,
  - Critical pressure and temperature,
  - and Hydrate formation conditions.
- Pseudo fluids of 90% CO_2 and 10% impurity are assumed.
- Inclined, horizontal and downhill pipelines are considered.



P – T Diagram of 90% CO_2 plus 10% impurity

3. Results

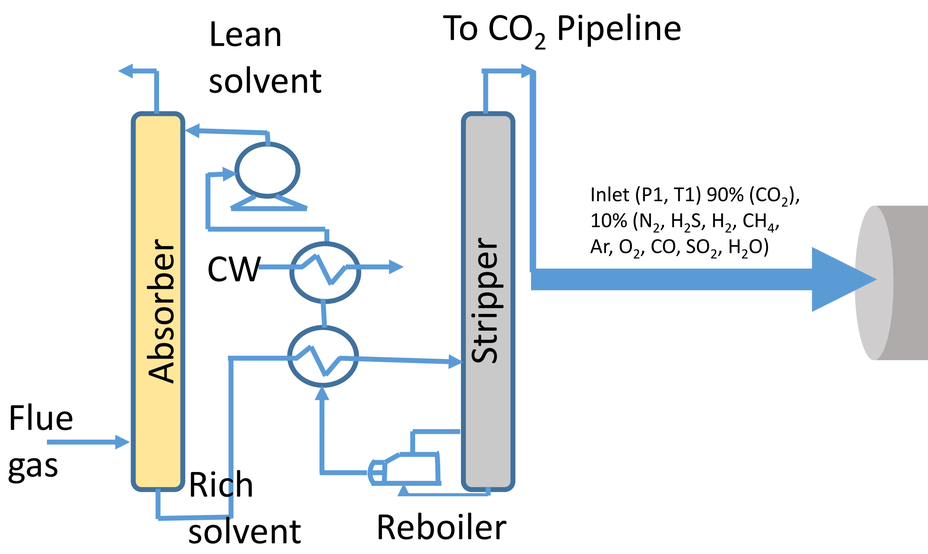
- In the horizontal pipeline, H_2 and SO_2 resulted to the highest and lowest pressure losses, respectively.
- In the inclined pipeline, SO_2 and H_2 caused the highest and lowest pressure losses, respectively.
- In the downhill pipeline, SO_2 had the highest pressure gain while H_2 was the only impurity that caused a pressure loss.
- H_2 and SO_2 respectively caused the highest and lowest temperature losses.
- H_2 and H_2S created the widest and narrowest 2-phase regions, respectively.
- Hydrate formation temperature was increased mostly by N_2 and decreased mostly by H_2S.
- All impurities increased the critical pressure. The highest and lowest increases are from H_2 and H_2S respectively.
- Only H_2S and SO_2 increased the critical temperature. The lowest critical temperature is with CH_4.



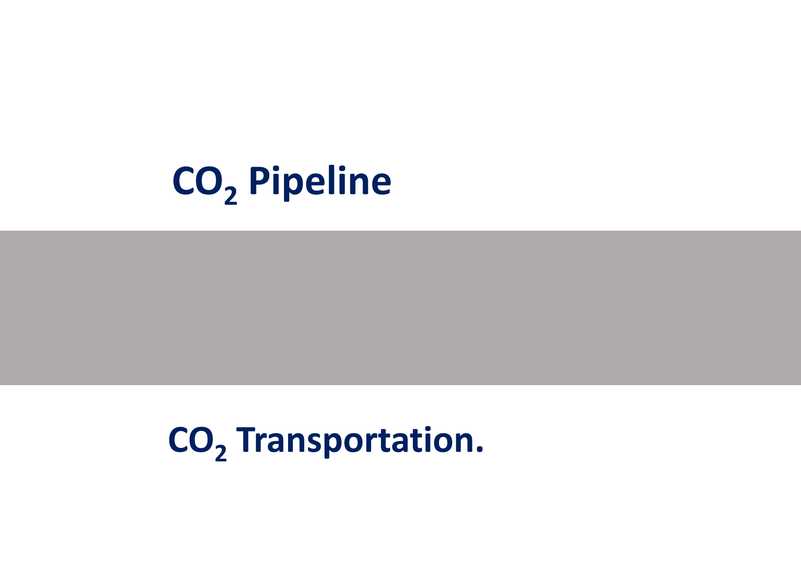
Comparative effect on temperature from 10% impurity in CO_2 pipelines.[3]

Critical pressure and critical temperature of 90% CO_2 and 10% impurity.[3]

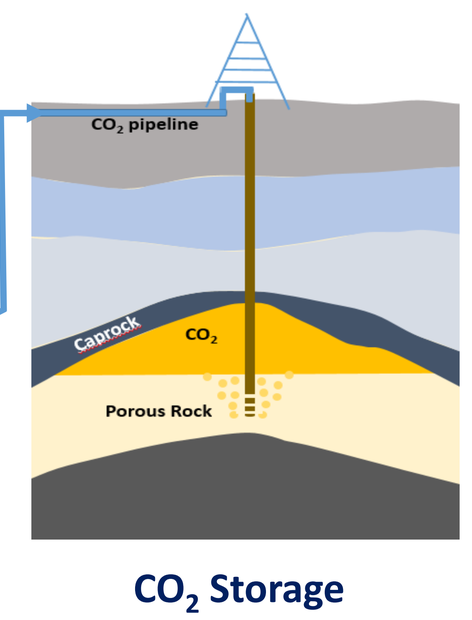
Components	Pure CO_2	CH_4	N_2	H_2S	O_2	SO_2	CO	NO	Ar	H_2
P_C (bar)	73.7	79.39	88.15	74.53	86.44	85.11	87.83	89.10	83.73	107.7
T_C (°C)	30.95	23.25	23.61	33.29	24.41	49.84	23.48	24.83	24.39	28.34



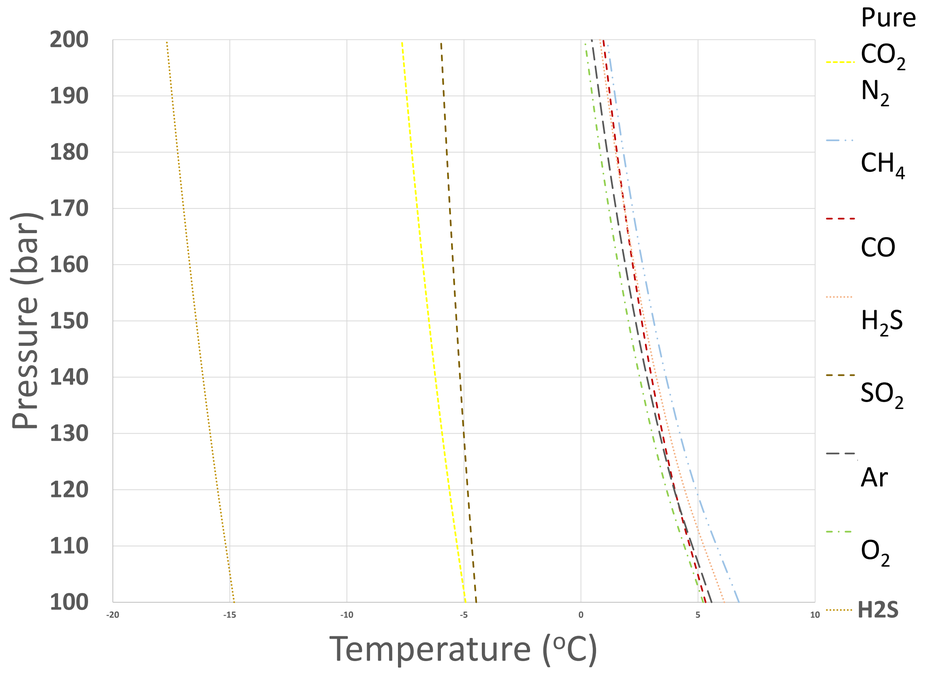
CO_2 Capture



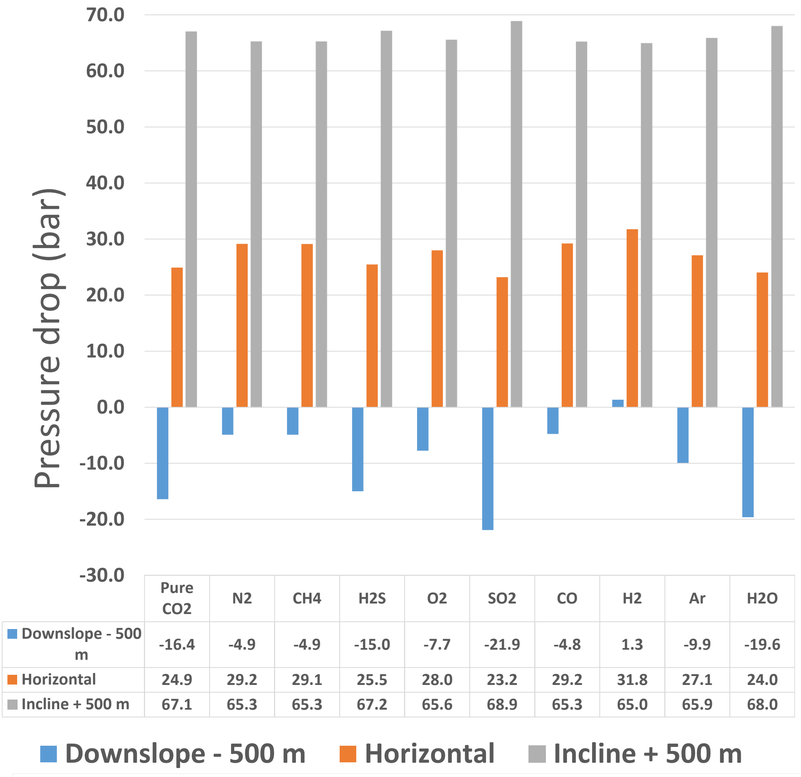
CO_2 Transportation.



CO_2 Storage



Hydrate formation temperatures of 90% CO_2 and 10% impurity between 100 and 200 bar



Pressure changes of inclined, horizontal and downslope pipelines

4. Conclusions

- Hydrogen has the greatest adverse effect on CO_2 pipelines.
- Effects of impurities on pressure also depend on pipeline profile.
- Gases with higher densities than CO_2 reduce pressure losses in horizontal pipelines but increase pressure losses in uphill pipelines.
- A low critical pressure is desirable because less energy is required to compress gas to supercritical state.
- All impurities increase critical pressures, increasing the energy penalty to compress gas.
- Only gases containing sulphur increase the critical temperature.

All impurities introduce errors in the process design of CO_2 pipelines.

References.
1. Forbes, S.M., et al., CCS Guidelines: Guidelines for Carbon Dioxide Capture, Transport, and Storage. 2008, Washington, DC: WRI. p. 148
2. IEAGHG, CO_2 Pipeline infrastructure, in 2013/18, December, 2013. 2014. p. 1 - 147.
3. Peletiri, S.P., N. Rahmanian, and Mujtaba, Iqbal M., Effects of Impurities on CO_2 Pipeline Performance. Chemical Engineering Transactions, 2017. 57: p. 355 - 360.