Development and evaluation of a CO_2 capture system using hollow fiber membranes for industrial emissions applications

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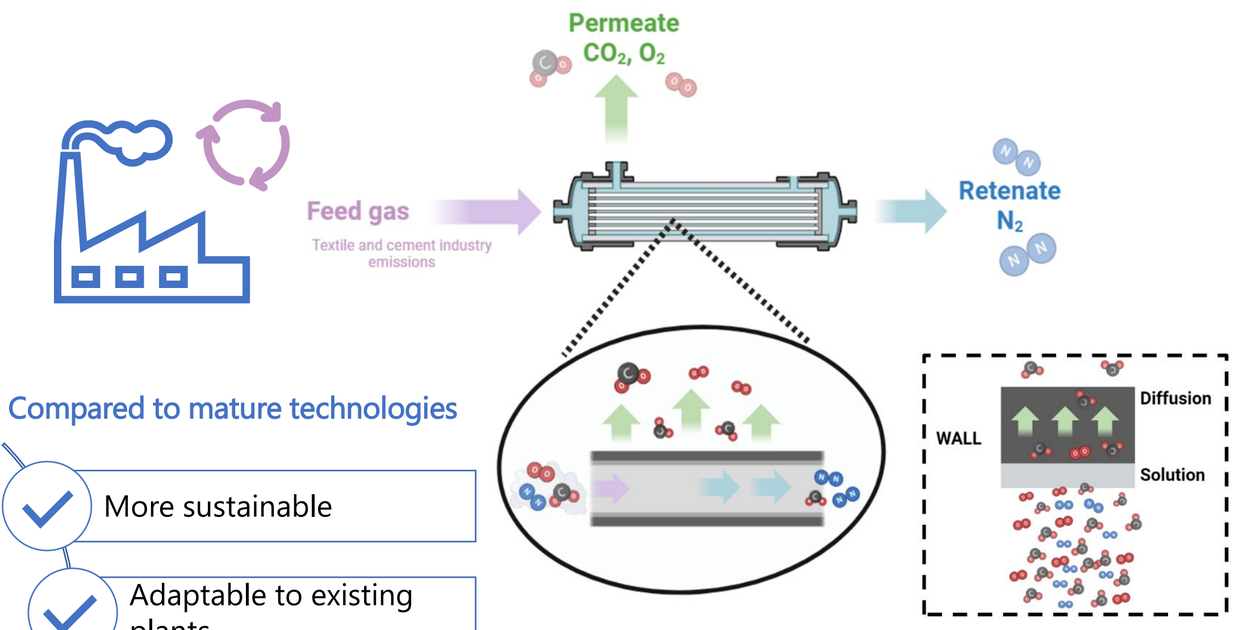
Introduction

This study aims to assess a CO_2 capture system real gases from the textile and cement industry on an experimental scale through a polysulfone hollow fiber membrane contactor, with the goal of developing a pilot-scale system



Compared to mature technologies

- More sustainable
- Adaptable to existing plants
- Lower energy requirements

Figure 1. Separation mechanism of gases in a dense hollow fiber membrane [1,2]

Results

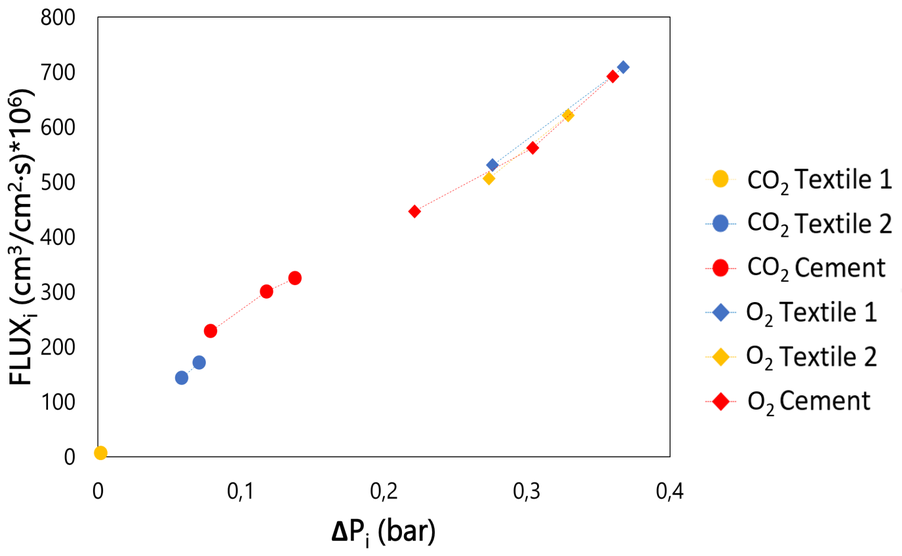


Figure 3. Permeate flow of CO_2 and O_2 from textile and cement industry samples as a function of Δp_i

Table 3. CO_2 permeance and selectivity of various samples at Q_{in}=650 ml/min and P=5 bar

Membrane	CO_2 Permeance (GPU)	CO_2/N_2 Selectivity	CO_2/O_2 Selectivity
Binary mixture (CO_2-N_2)	50.09	6.26	-
Textile 1	20.73	3.35	0.86
Textile 2	32.65	6.27	1.32
Cement	36.47	6.95	1.38

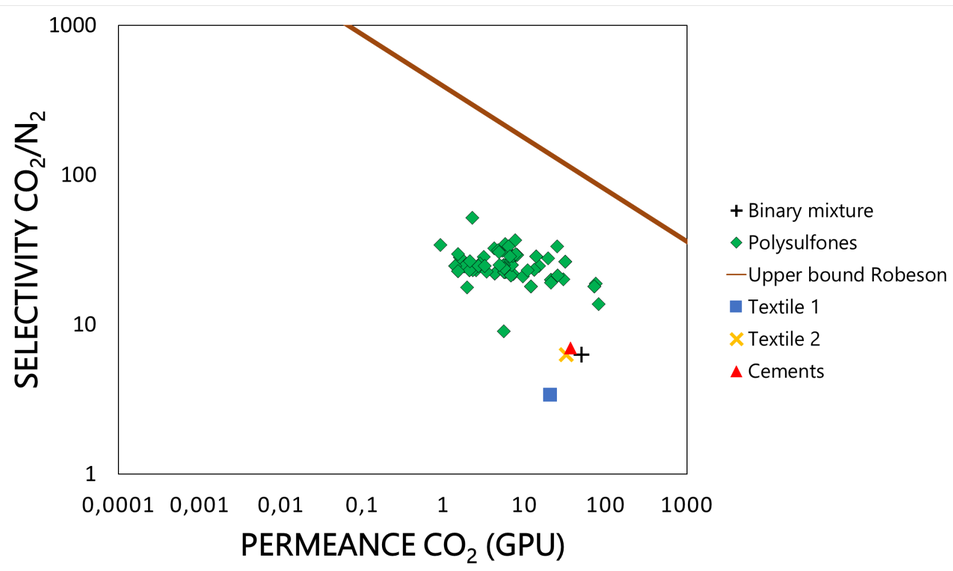


Figure 4. Comparison of CO_2 permeance and selectivity for various samples against Robeson's upper bound and other polysulfone membranes. Adapted from [3]

Methodology

Membrane characteristics

Manufacturer: Airrane
Material: Polysulfone
Geometry: Hollow fiber
Specific area (cm^2): 1822
No. of fibers: 2000

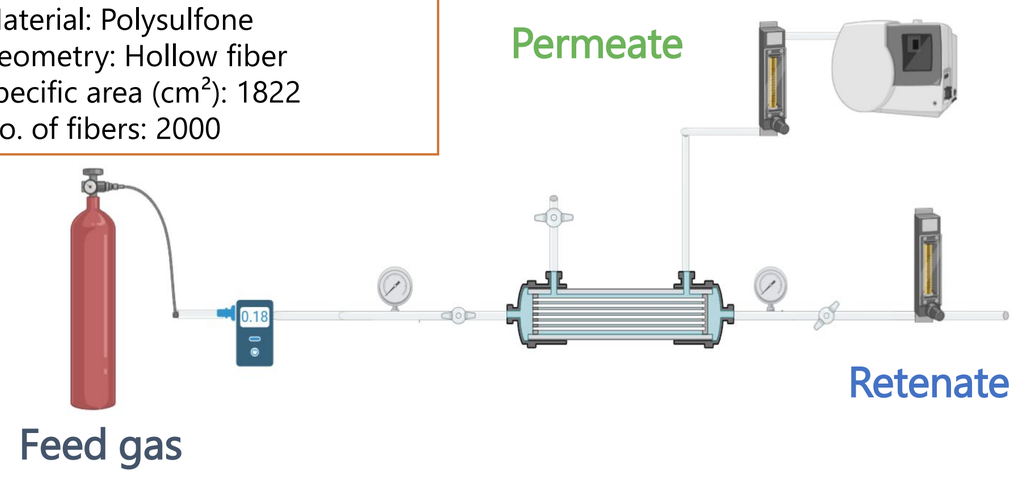


Figure 2. Diagram of system for gas separation with membrane

Table 1. Characteristics of industrial gases

Origin	Compound	Composition	Company
Textile industry 1	CO_2	0.5%	Textil Santanderina, S.A.
	O_2	20.0%	
Textile industry 2	CO_2	3.6%	
	O_2	13.4%	
Cement industry	CO_2	6.9%	Cementos Portland Valderrivas
	O_2	14.5%	

Table 2. Experimental conditions

Variable	Value
Feed pressure (bar)	4,5,6
Permeate pressure (bar)	1
Feed flowrate (mL/min)	650
CO_2 concentration (%)	0.5, 3.6, 6.9

*In industrial gases it is assumed that the remainder is %N_2

Conclusion

- CO_2 permeate flux significantly depends on feed concentration, unlike O_2, which is independent.
- For the lowest CO_2 concentration stream, permeation is negligible, but reaches up to 325 cm^3 cm^{-2} s^{-1}*10^6 for cement gases.
- O_2 competes with CO_2 for membrane transport sites, notably affecting textile gas 1.
- CO_2 /N_2 selectivity remains similar for cement gases and textil gases 2 but decreases by nearly 50% for textile gases 1

Further work

1. Evaluate technically and economically the implementation of membranes with higher CO_2/O_2 selectivity .
2. Design the system with additional stages employing more steps.

Acknowledgments

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