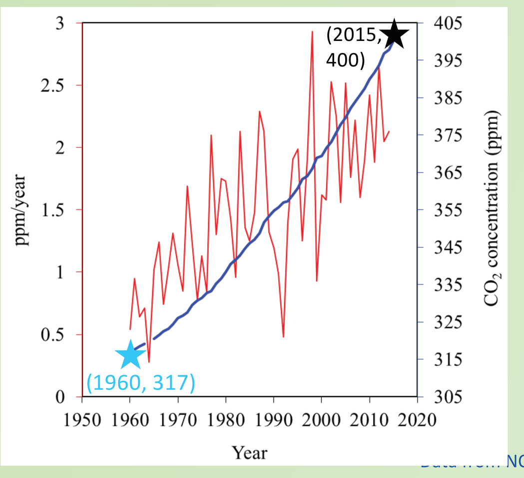
Development of high performance CO_2 adsorbent using response surface methodology

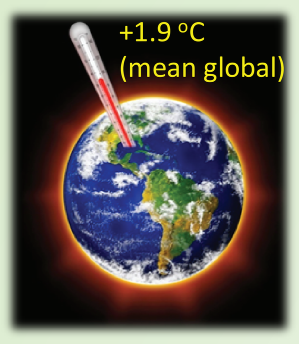
Abstract

The response surface method (RSM) was used to optimize the conditions for the impregnation of blended amines into mesostructured cellular silica foam (MSU-F) to prepare effective solid sorbents for CO_2 capture. The effects of the amounts of tetraethylenepentamine (TEPA), diethanolamine (DEA), and MeOH in the wet impregnation mixture on the amounts of CO_2 adsorbed were investigated. The optimum sorbent was characterized by N_2 adsorption-desorption, FT-IR spectra, and CO_2 adsorption. Under the adsorption conditions 40 °C and 100 kPa CO_2, the optimum sorbent showed fast kinetics and an excellent CO_2 adsorption of 5.64 mmol/g. We also found that the amounts of CO_2 adsorbed by the optimum sorbent depended substantially on the adsorption temperature. The highest CO_2 adsorption, 6.86 mmol/g, was obtained at 50 °C and 100 kPa. The FT-IR spectrum indicated that CO_2 was adsorbed into the adsorbents through the formation of carbamate species.

Introduction

CO_2 emissions & global warming

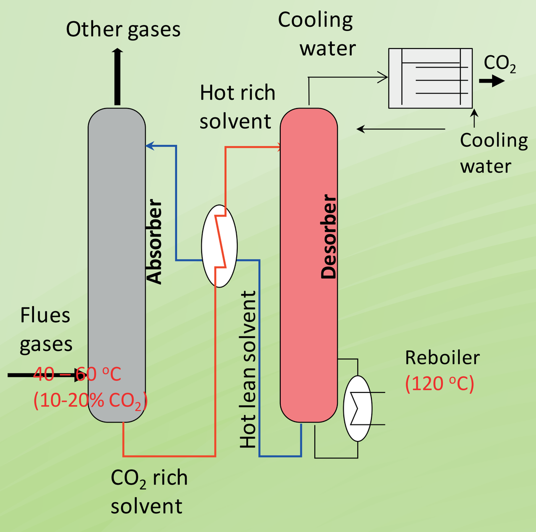




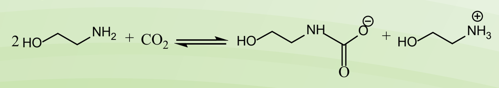
Hundreds of millions of people could lose their lives.

Liaquat *et al. Atmos. Environ.* 44 (2010) 3869.

Amine scrubbing solution (Absorption)



Capture reaction

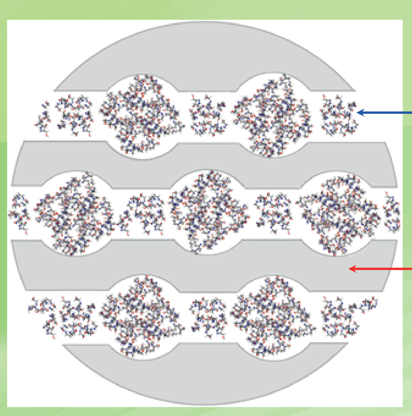


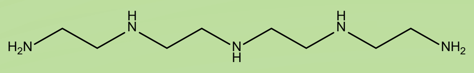
Disadvantages

- High energy cost for solvent regeneration due to the water solvent (key)
- Equipment corrosions and solvent losses

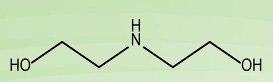
Sumida *et al. Chem. Rev.* 112 (2012) 724.

Amine solid sorbents



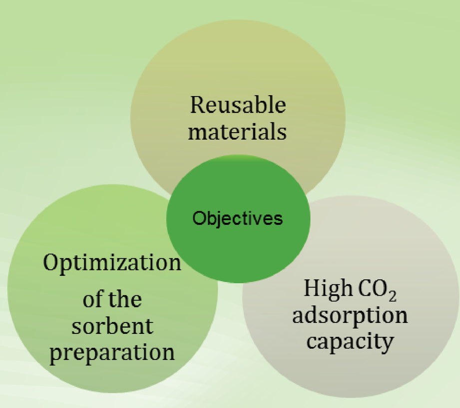


Tetraethylenepentamine (TEPA)

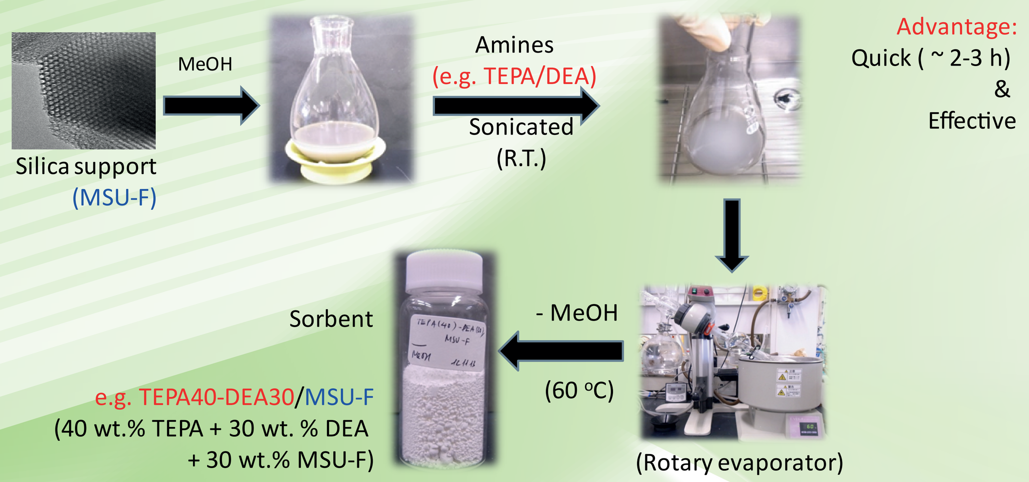


Diethanolamine (DEA)

Objectives

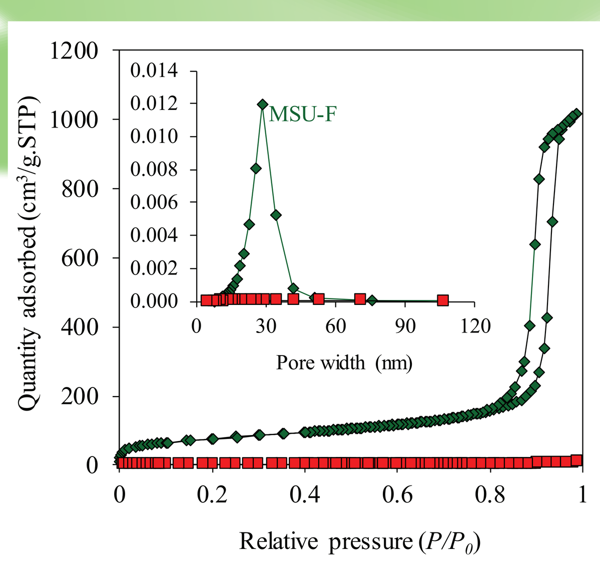


Experimental Section



Results & Discussions

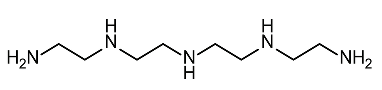
Textural properties



Materials	Surface area (m^2/g)	Pore size (nm)
MSU-F	275	28
TEPA44-DEA28/MSU-F (optimum sorbent)	2.43	5.91

Amines were loaded into the support.

In-situ FT-IR analysis



TEPA

IR bands assignments:

Silica:

3740 cm^{-1} (isolated OH);

1645 cm^{-1} (water bending)

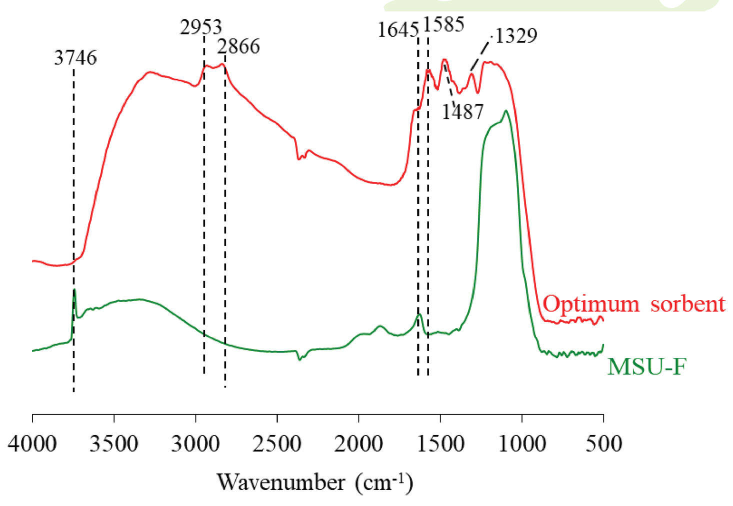
TEPA-impregnated:

3292, 1589 cm^{-1} (NH)

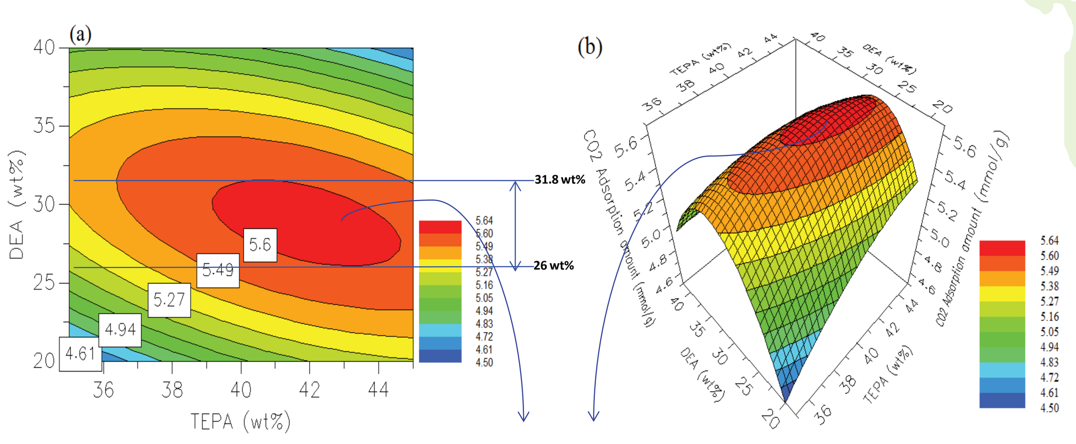
2920, 2821 cm^{-1} (CH_2 stretching)

1460 cm^{-1} (C-

Amines were loaded into the support.

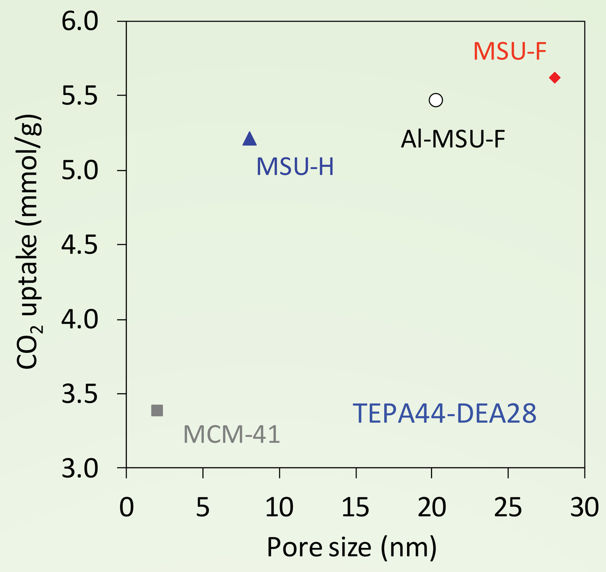


Response surface plots



Optimum region, TEPA44-DEA28 (CO_2 uptake > 5.6 mmol/g)

Effects of supports

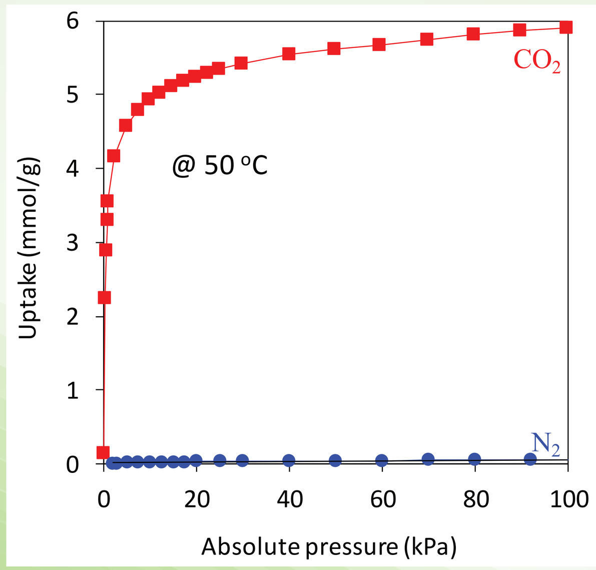


@ 40 °C, 100 kPa

Support	MCM-41	MSU-H	Al-MSU-F	MSU-F
Pore size (nm)	2.1	8.0	20.2	28
CO_2 uptake (mmol/g)	3.42	5.42	5.50	5.64

- Strong effects of pore sizes on the CO_2 uptake;
- With largest pore, MSU-F is the best support.

CO_2/N_2 selectivity

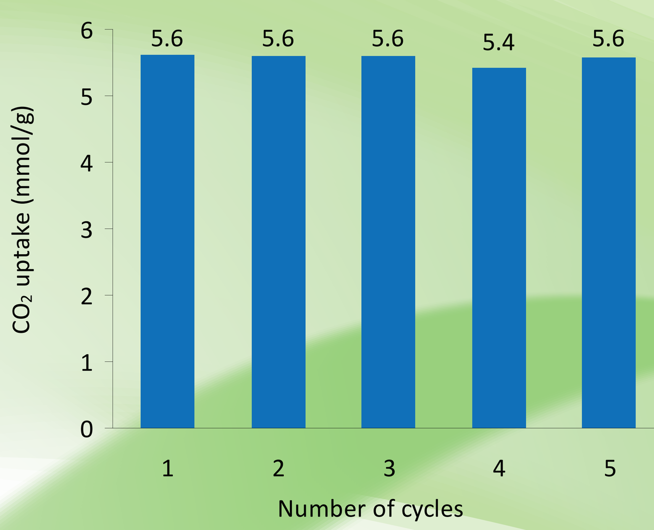


TEPA44-DEA28/MSU-F

- CO_2 uptake: 6.00 mmol/g
- N_2 uptake: 0.05 mmol/g

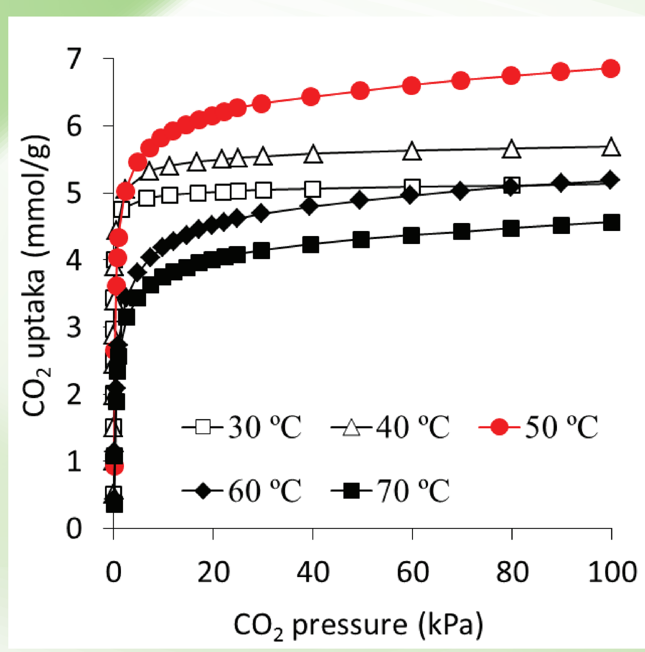
Excellent selectivity of > 100 for CO_2/N_2

Working capacity of optimum sorbent



High working capacity.

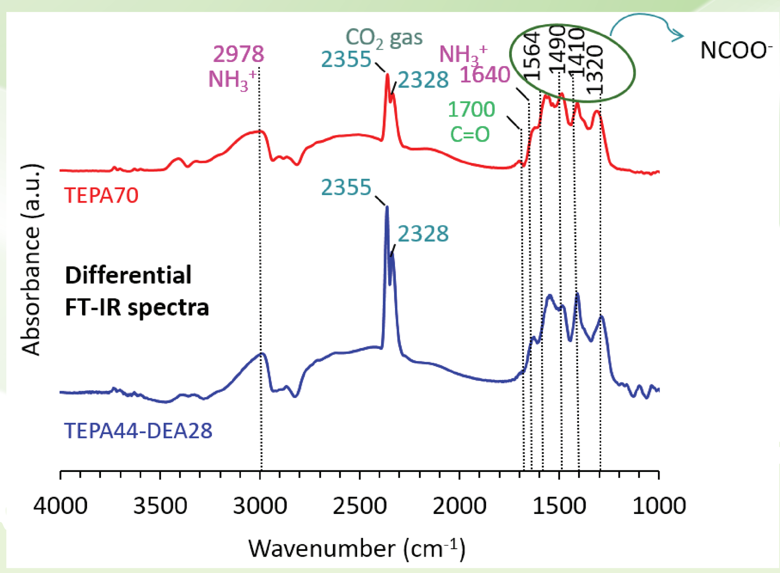
CO_2 adsorption performance of optimum sorbent



High CO_2 adsorption performance (~ 7 mmol/g at 100 kPa, 50 °C)

Optimum sorbent: TEPA44-DEA28/MSU-F-58.2

Carbamate formation



CO_2 was adsorbed onto the sorbent through the formation of ammonium Carbamate.

Conclusions

- TEPA44-DEA28/MSU-F is the optimum sorbent was developed based on the surface optimization methodology;
- Optimum temperature: 50 °C (6.86 mmol/g);
- TEPA44-DEA28/MSU-F showed a good cyclic stability;
- Excellent selectivity for CO_2/N_2
- CO_2 was adsorbed on to the sorbents through the formation of carbamate species.

References

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