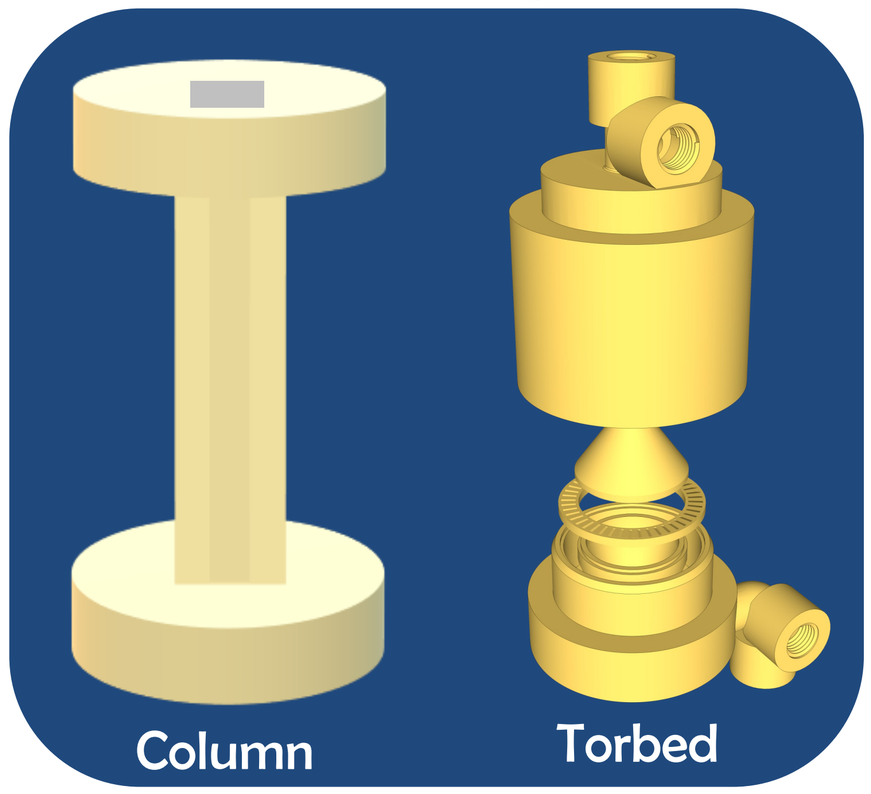
Intensified Carbon Capture using adsorption with potential uses in industry

Daniel Codd; daniel.codd99@gmail.com / 07526371672
Dr Vladimir Zivkovic & Dr Jonathan McDonough
School of Engineering

Introduction

- Industrial processes account for 25% of total EU CO_2 emissions, even while operating at near optimum efficiency
- CO_2 capture and storage offers the potential to reach required CO_2 targets set for 2050
- Current CO_2 capture and storage technologies generate significant energy penalties. The use of solid adsorbents offers ~30-50% less energy consumption than current state-of-the-art liquid absorbent alternatives [1]

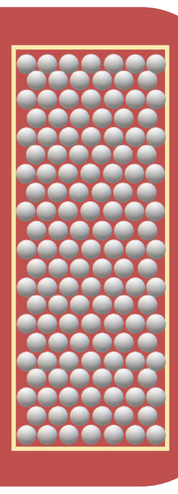


The Aims of this Project

- Observe how bed configuration & operating conditions affect CO_2 capture
- Screen activated carbon adsorbents in novel 3D printed geometries

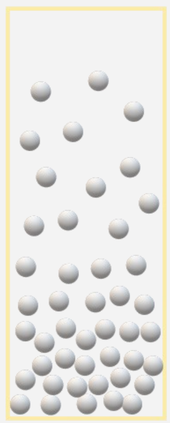
Packed bed

- Column configuration; fully packed
- Stationary sorbent
- Air flows through fixed stationary sorbent
- Large pressure drop



Fluidized bed

- Column configuration; partially filled
- Mobile sorbent
- Lower pressure drop than packed bed



Torbed

- Uses static blades to create swirling air flow
- Highly mobile sorbent
- Lower pressure drop than fluidized bed

Breakthrough Curve

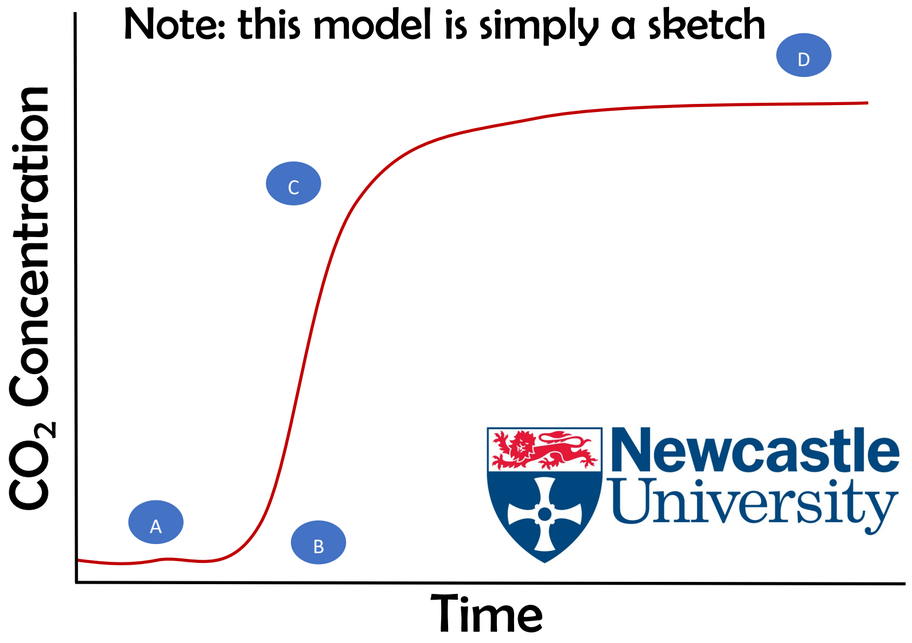
0—>A, The amount of time it takes the CO_2 to reach the sorbent bed

A—>B, Represents the time in which the unsaturated sorbent is most effective

B—>C, Sorbent slowly adsorbs more CO_2, causing it to 'break through' the bed

C—>D, The sorbent becomes saturated in CO_2. Once the sorbent is fully saturated the measured outlet CO_2 concentration matches the inlet concentration

Capacity/uptake rate are determined by the difference in breakthrough curves of the activated carbon and an equivalent inert material



Modelling the Data

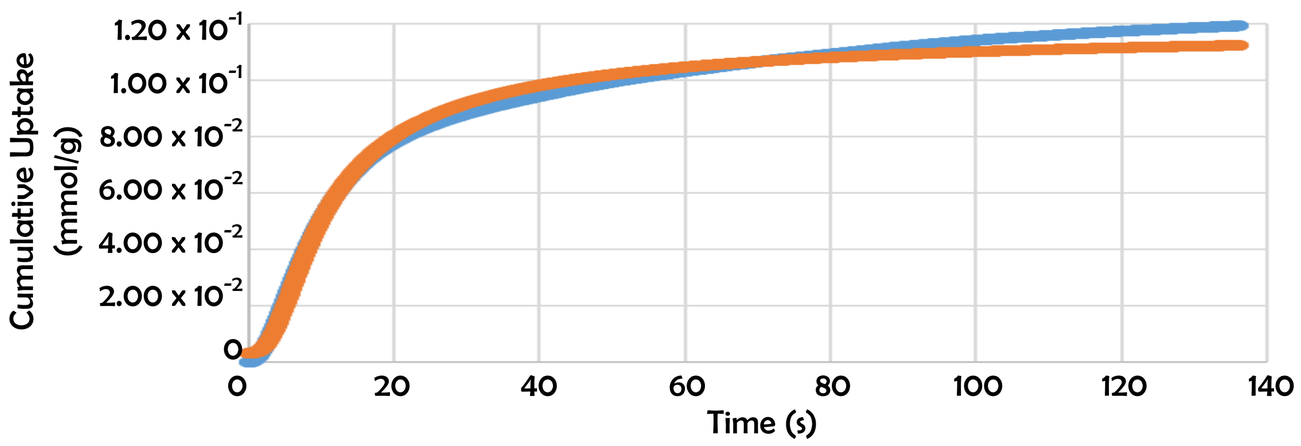
- Cumulative uptake curves were plotted and used to gain kinetic model parameters for each experiment; three models were considered.
- Fractional order was chosen over 1st and 2nd order models using the residual sum of squares method.
- The general form of the fractional order equation is given below:

$$Q_t = Q_e - \frac{1}{\left[\left[\left\{\frac{(n-1)K3}{m}\right\}t^m + \left\{\frac{1}{{Q_e}^{n-1}}\right\}\right]^{\frac{1}{n-1}}\right]}$$

Q_t — Uptake at time t
Q_e — Uptake at equilibrium
n, m, K3 — constants t — time

Packed Bed					
Air flowrate L/min	CO2 flowrate SCCM	Capacity mmol/g	K3	n	m
5	100	0.033	0.506	4.611	4.010
	250	0.071	0.279	1.872	1.521
	500	0.114	3.893	3.932	2.760
Humid Packed Bed					
Air flowrate L/min	CO2 flowrate SCCM	Capacity mmol/g	K3	n	m
5	100	0.039	3.729	3.772	3.418
	250	0.064	3.506	3.538	2.957
	500	0.101	4.404	4.459	3.796

Blue curve - Experimental data Orange curve - Fractional order model



Conclusions

- For all experiments, CO_2 uptake was shown to be mass transfer controlled. In practice, more CO_2 present displayed higher capacity of activated carbon.
- Fluidized bed energy requirements are less than the packed bed.
- Packed bed displays larger capacity per bed.

[1] - https://rccs.hw.ac.uk/current-projects/222-novel-adsorbents-applied-to-integrated-energy-efficient-industrial-co2-capture.html