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ABSALT: Accelerating Basic Solids Adsorbent Looping Technology

Colin Snape (Univ. of Nottingham Coordinator)
In attendance: Stephan Hueffer and Tobias Merkel, BASF
Lee Stevens and Wei Li, Univ. of Nottingham

Partners: University of Nottingham, UK; PQ Corporation, UK; BASF, Germany, CEMEX, Switzerland; University of Ulster, UK; University of Bologna, Italy; CPERI-CERTH, Greece
Sub-contractor: Korean Institute of Energy Research (KIER).

7 partners, 4 participating countries, 3 industrial.

The goal is to demonstrate that basic silica-polyethylenimine (PEI) in solids adsorption looping technology (SALT) can achieve low capture costs, achieved through optimising silica-PEI composition, techno-economic and life cycle analyses, with pilot-scale testing.

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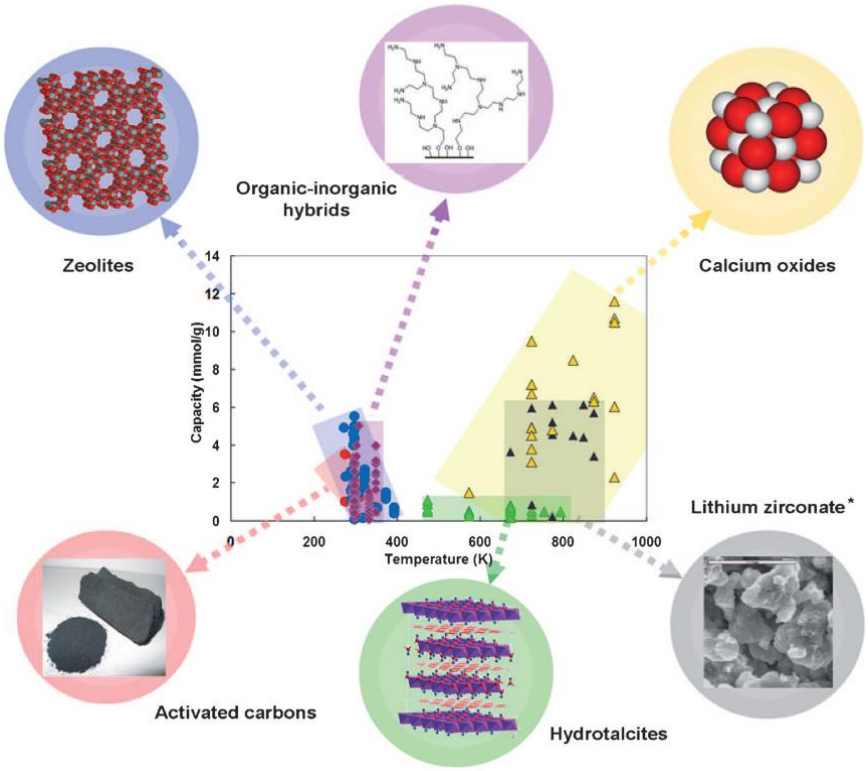
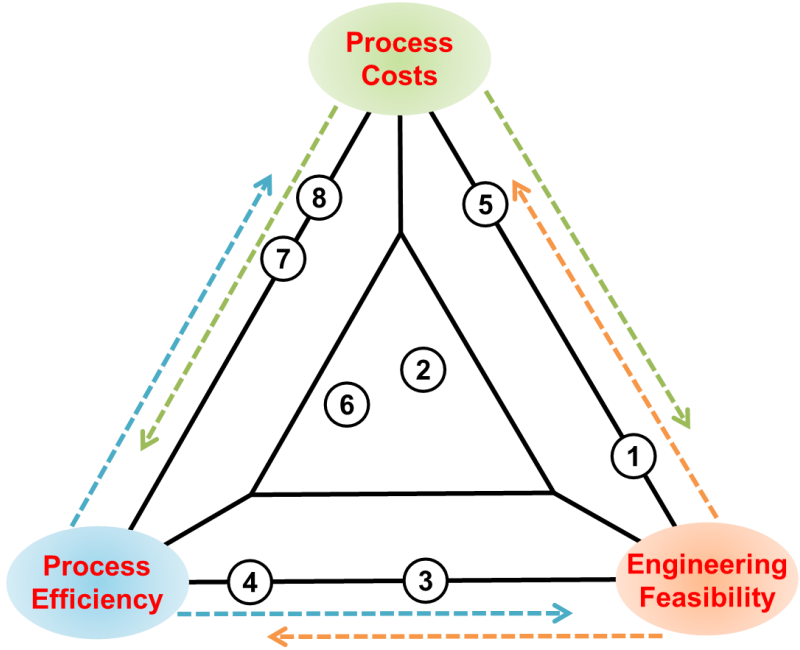
Background and Motivation
– moving from lab. to pilot-scale with solid adsorbents as a next generation capture technology

- Solid adsorbents are still at early stage of development and have not been investigated extensively at demonstration scale.



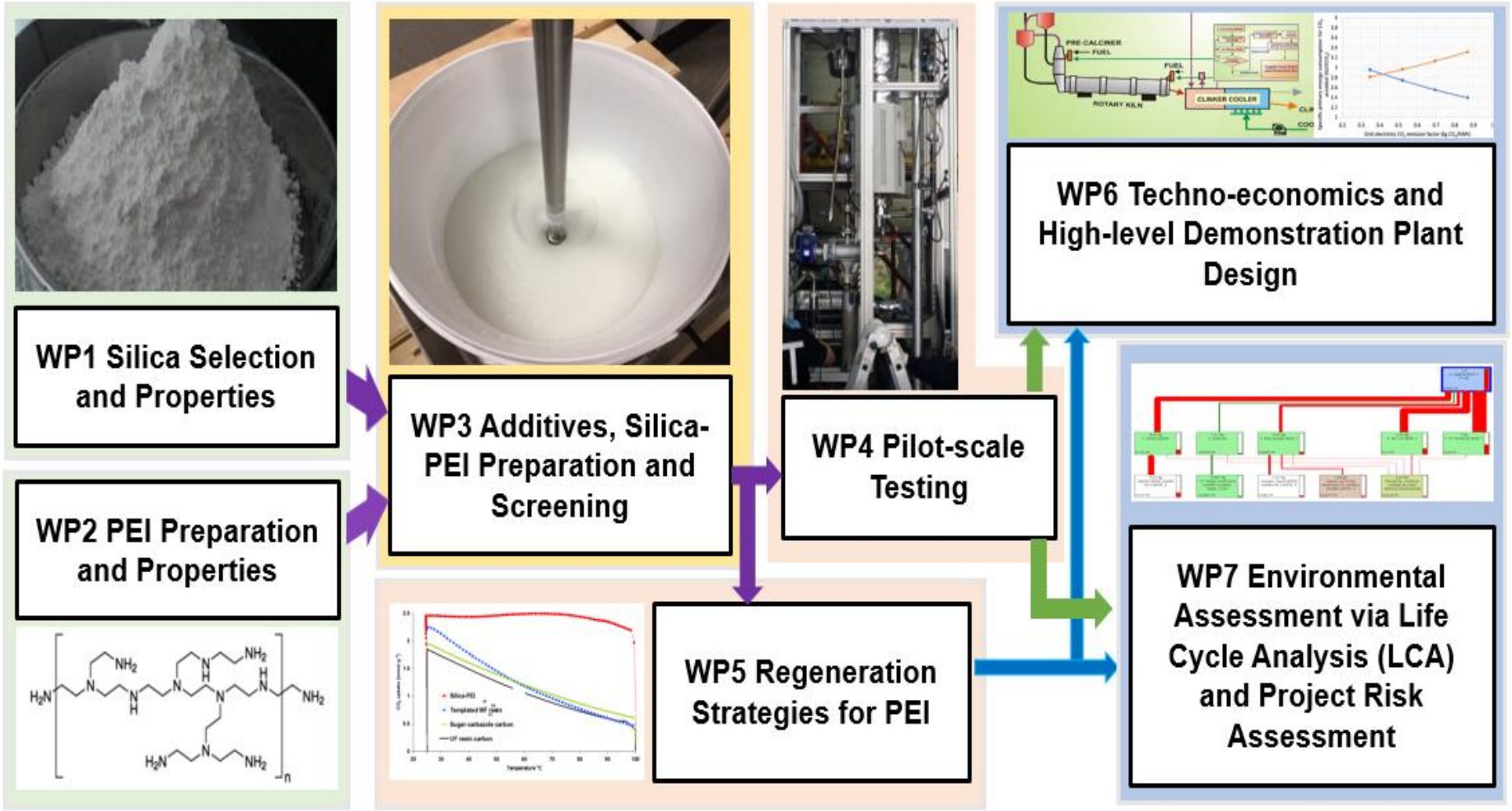


1-Precursor and Preparation Costs
2-Adsorption Heat
3-Physical Shape and Mechanical Strength
4-Density
5-Chemical Stability
6-Adsorption Dynamics
7-Adsorption Capacity and Selectivity
8-Hydrophobicity

R. Xiong, et al., Chem. Eng. Sci., 58 (2003) 4377.

- ***None of these has reached small demonstration scale for post-combustion capture!***
- ***Many criteria need to be met regarding performance, stability and cost.***

Schematic Representation of ABSALT



- Extensive linkages between WPs and the various partners.

WP2: PEI Preparation and Properties

Stephan Hueffer, Tobias Merkel and Ivette Garcia, BASF

Impact

- Findings have contributed to the two patents filed on PEI alkoxylation and the preparation of silica-alkoxylated PEI.
- Alkoxylation technology using no solvents or minimal amount of water can be scaled up further when required.

Highlights

- Optimal alkoxylation preparations identified from screening 48 samples.
- Successfully scale-up to 100 kg production with 4 samples prepared.
- The achievements are:
  - No solvents other than water
  - The viscosity is low enough for the alkoxylation reaction.
  - Safety aspects have been addressed using the pilot-scale preparations.

Silica-PEI performance and scale-up

Colin Snape, Lee Stevens and Wei Li, Univ. of Nottingham; Simon Stebbing, PQ Corporation; Stephan Hueffer, Tobias Merkel and Ivette Garcia, BASF

WP 1-3 form part of overall objective to optimise silica-PEI performance.

Initial Plan No significant deviations with 350 samples being screened.

- The impact of anti-oxidants has been covered (Task 3.1)
- The ground-breaking results with the alkoxylated PEIs meant there was less emphasis on chelating agents and surfactants (Tasks 3.2 and 3.3).

Pilot-scale testing (WP4)

- Optimal silica-alkoxylated PEI formulations for pilot- scale testing.
- 5 and 100 kg batches prepared by PQ Silicas.

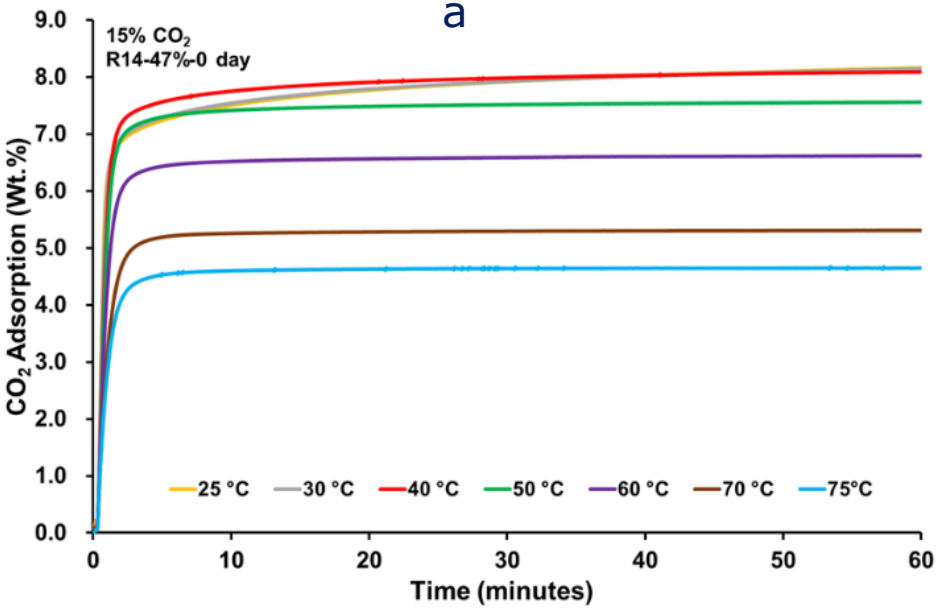
Highlights include:

- Identifying the water content after drying needed to prevent oxidative degradation.
- Patent filed on the preparation of silica-alkoxylated PEI using the minimal amount of water.
- Optimising silica-alkoxylated PEIs for capture at different temperatures, leading to application for DAC.

WP 3: Highlight

Optimising silica-alkoxylated PEIs for capture at different temperatures

a



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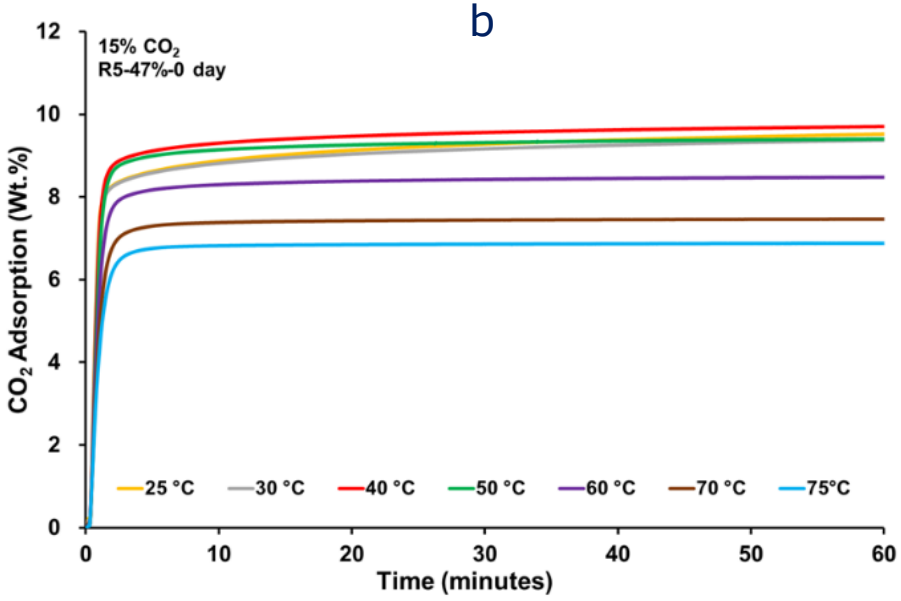
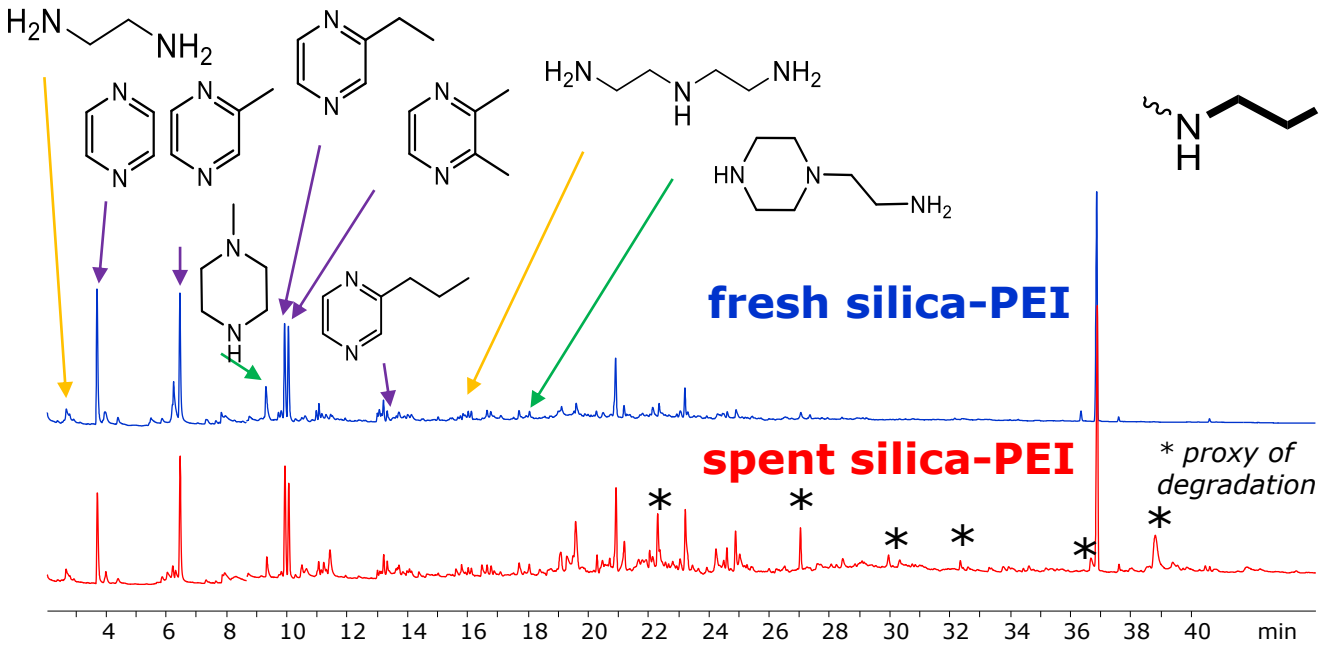
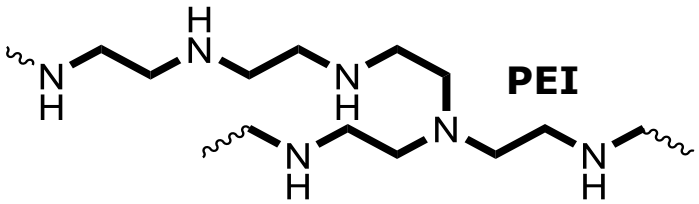


- Alkoxylation has the advantages of shifting the maximum CO_2 uptake to lower temperatures which also reduces the desorption temperatures, faster kinetics and improved oxidative stability.
- Two samples optimised to maximum CO_2 uptake over the temperature range of 25-60^{o}C to apply SALT to both cement and other industrial processes at 50-60^{o}C (sample b) and direct air capture at 25^{o}C (sample a).

WP 5 Valorisation of spent silica-PEI: Highlight

Mechanisms identified leading to high yields of pyrazines

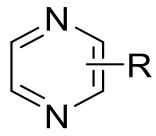




cyclisation

aromatisation

alkylation



ALKYLPYRAZINES

SILICA

- Py-GC-MS of model PEI, fresh and spent Si-PEI evidenced main chemical families of pyrolysis products.
- Pyrograms of Si-PEI were dominated by pyrazines.
- Mechanisms of formation of pyrolysis products and effect of silica to favour pyrazines postulated.

ABSALT Main Outcomes and Impact

- Two patents filed (WP1-3), three peer-reviewed journal papers on techno-economics and silica-PEI regeneration
- Demonstrated that alkoxylation of PEI vastly improves oxidative stability when supported on silica and enables lower regeneration temperatures to be used.
- The production of alkoxylated PEI has successfully been scaled-up to 100 kg for pilot-scale testing (WP4). Commercialisation is feasible.
- Pyrolysis can convert spent silica-PEI adsorbent into pyrazines, a valuable class of compounds, recovering the silica for possible recycling. (WP5).
- The techno-economic study has demonstrated the potential benefits of SALT in terms of lower operating costs compared to advanced amine systems (WP6).
- SALT offers positive environmental and health in terms of process operation and adsorbent manufacture compared to amine scrubbing (WP7).
- A high-level design to demonstrate the ABSALT concepts at industrially relevant conditions (TRL 6), will allow end users of cement plants to evaluate this technology.

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