Towards Sustainable Research Culture @ QMUL:

Topics, Activities and International Partnering in CO_2-Usage and Infrastructure

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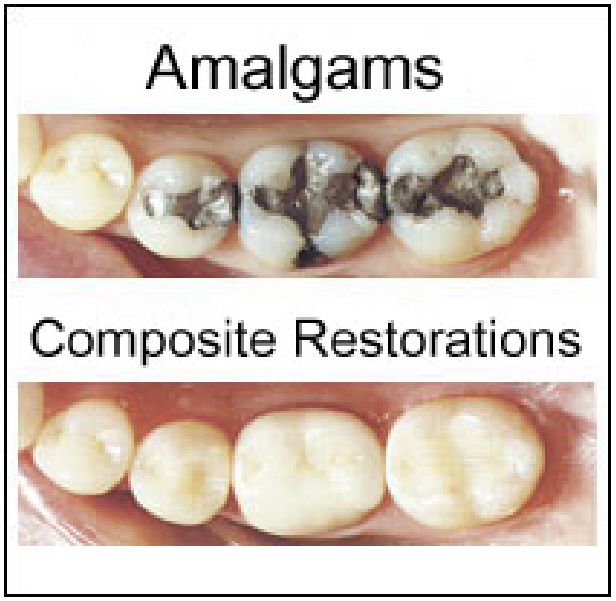
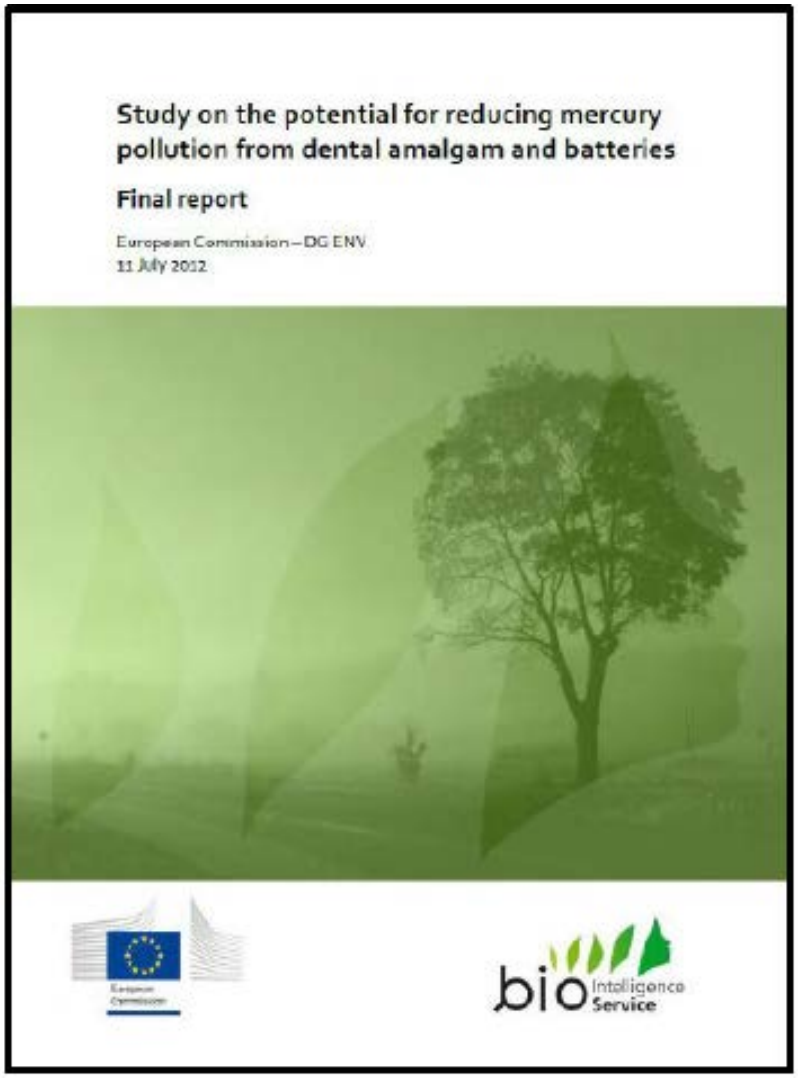
GOAL: ISO14001 Platinum Accreditation @ QMUL

3 year journey

- Objectives:
- Integrate sustainability into research in SPCS and across faculty (S&E) and beyond
- Joint-projects & funding spanning sustainability unit & research (in SPCS)
- Longer-term: sustainability in curriculum in SPCS, across S&E and beyond

Research Foci: Cement Functionality & Durability
I - Medical & Dental Cements

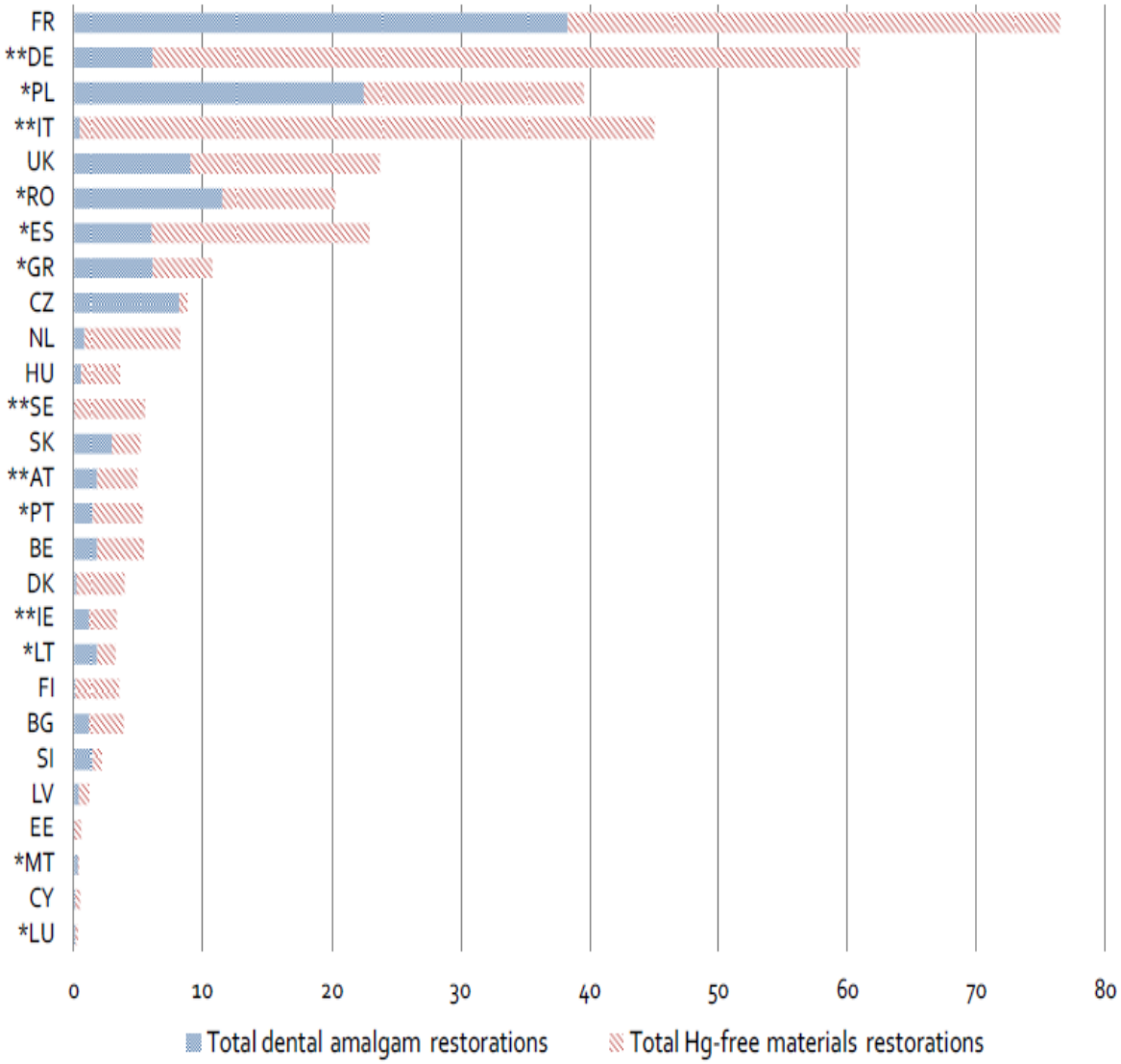




- **Hg-Amalgams remain the performance & mechanical 'poster-child', outlasting recipient**
- **Hg-Amalgams used more than ever @ ~100 M /yr (USA). 1g x 10^8 = 100 tonnes / yr**

The United Nations Environmental Programme (UNEP) reported that the dental sector uses about 340 tons of mercury in dental amalgams each year. It is estimated that 100 tons of dental mercury enters the waste stream annually.

Phasing-out Hg-Usage in Europe



- wealthy EU-states like France and the UK leading users of dental-Hg (00's of tonnes)
- most promising alternative GICs are unknown by a large number of dental practitioners (up to ~44% in UK)
- Main reasons for continued use of Hg-amalgams = cost, lack of knowledge on GICs !!!
- GICs used remain TOO BRITTLE
- R&D and commercial aspects estimated at 5bn € / yr

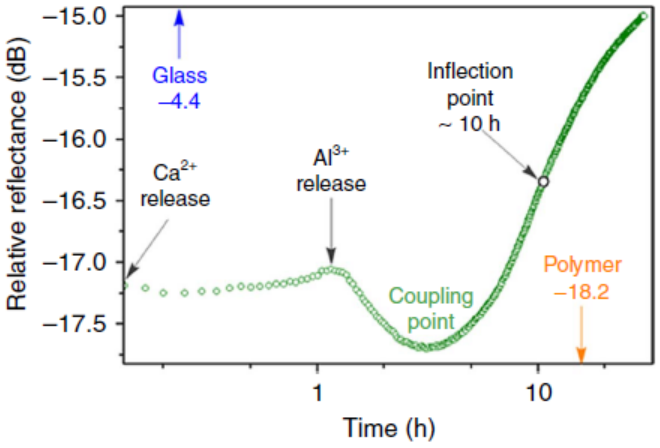
Shortcomings & Successes of the GIC Research

nature COMMUNICATIONS

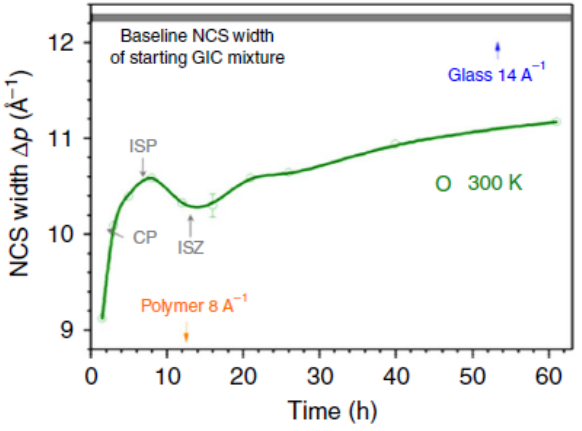
Atomic and vibrational origins of mechanical toughness in bioactive cement during setting

Kun V. Tian[1], Bin Yang[2,3], Yuanzheng Yue[4,5], Daniel T. Bowron[6], Jerry Mayers[6], Robert S. Donnan[3], Csaba Dobó-Nagy[1], John W. Nicholson[7], De-Cai Fang[8], A. Lindsay Greer[9], Gregory A. Chass[10] & G. Neville Greaves[4,9,11]

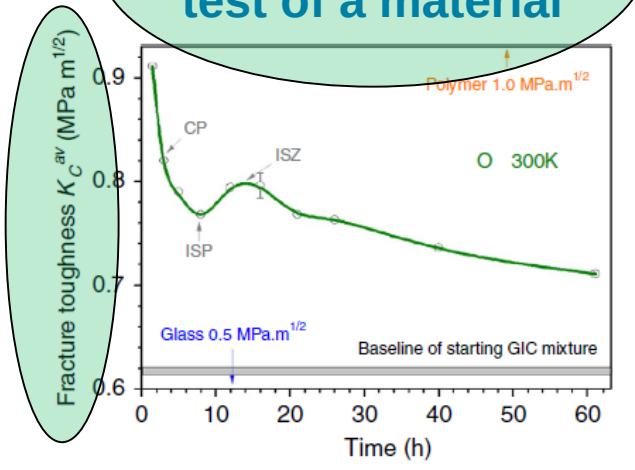
1st ever NON-destructive fracture test of a material



Coherent-THz Spectroscopy

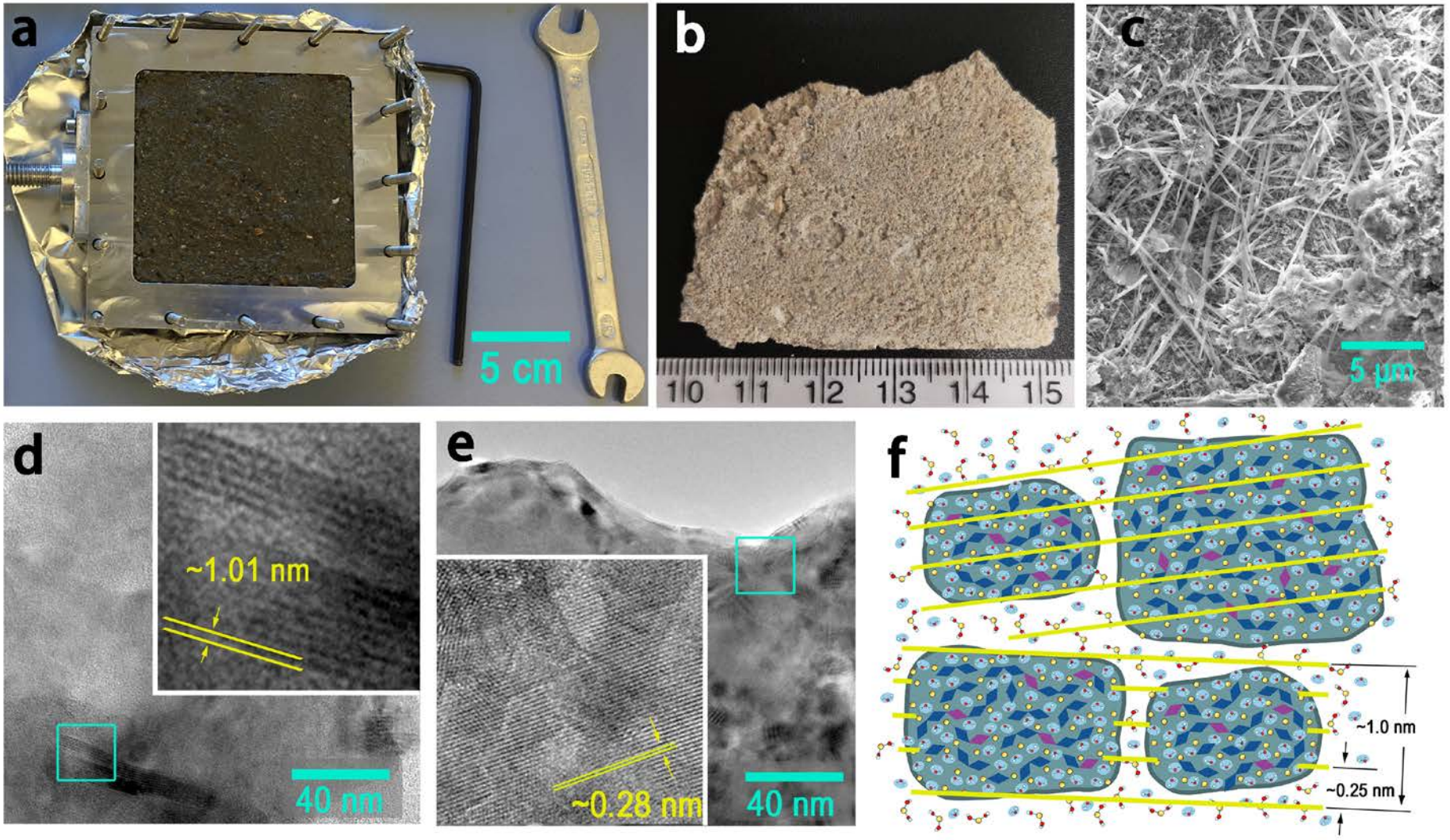


Neutron Compton Scattering



Engineering Scale Fracture (MPa)

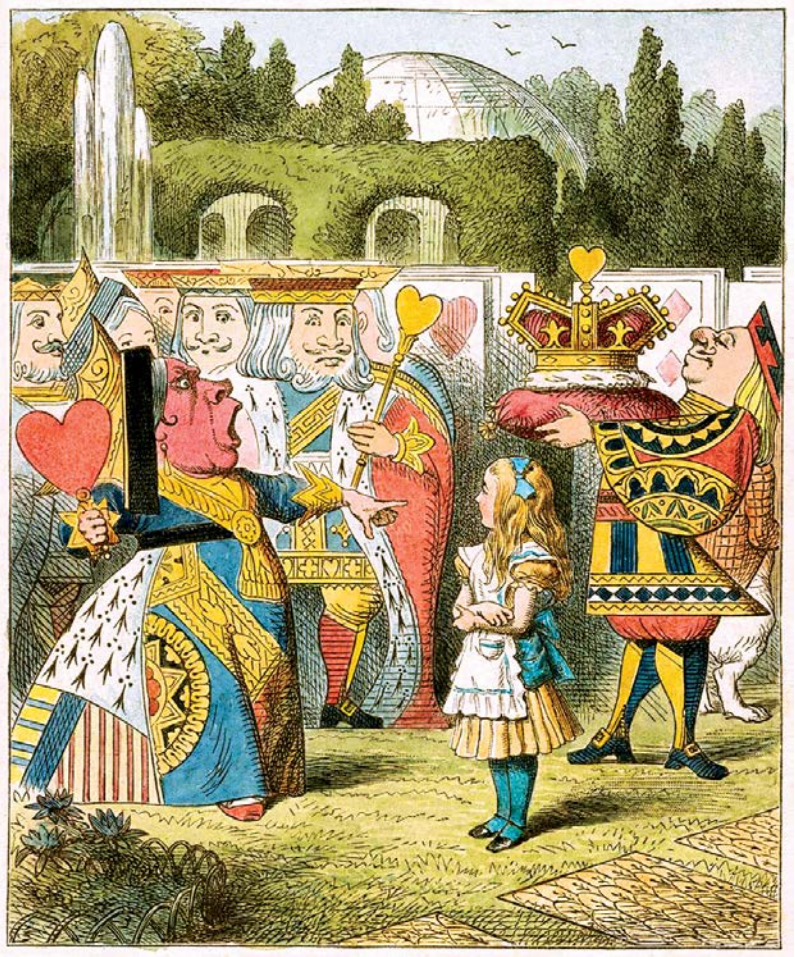
Research Foci: Cement Functionality & Durability
II - Concrete & Infrastructure



Ensuring Complexity – Failing to Bridge the Divide

“I could have done it in a much more complicated way, said the Red Queen immensely proud.”

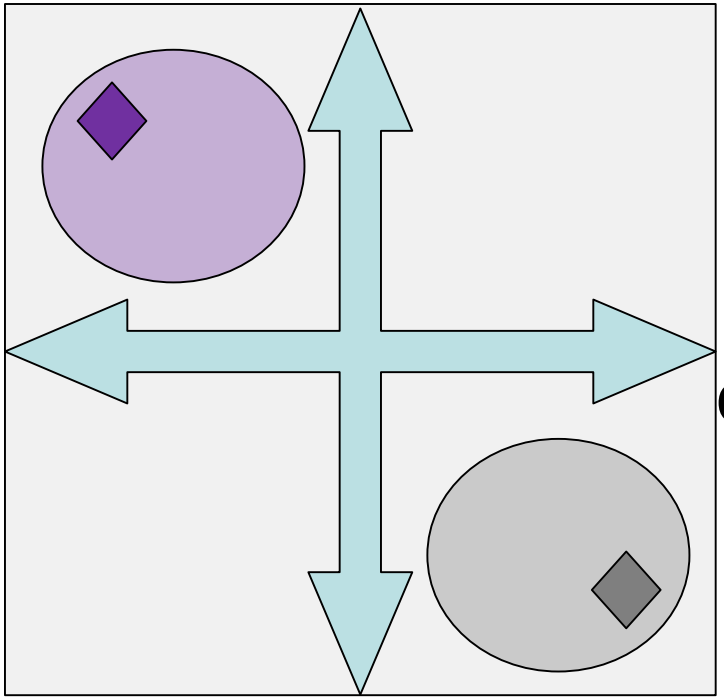
– Lewis Carrol –
In Alice’s Adventures in Wonderland (1865)



Towards Sustainability – Environmental, Economical, Temporal

Academic
Impractical
Costly

'Lab-Crete'

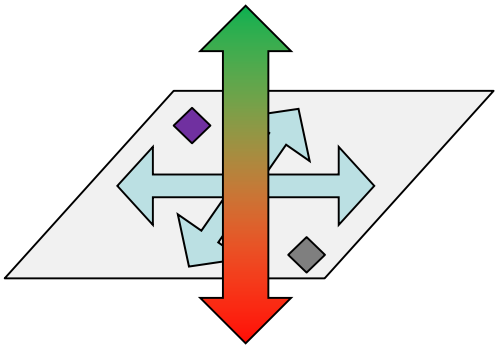


Ideal
Pure
Behaving

Real
Impure
Complex

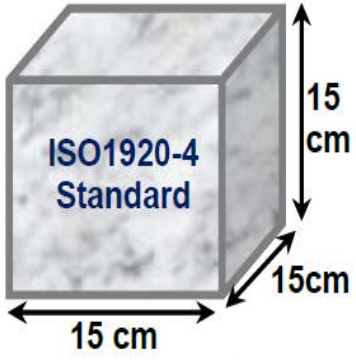
Industrial
Practical
Profitable

'Building'



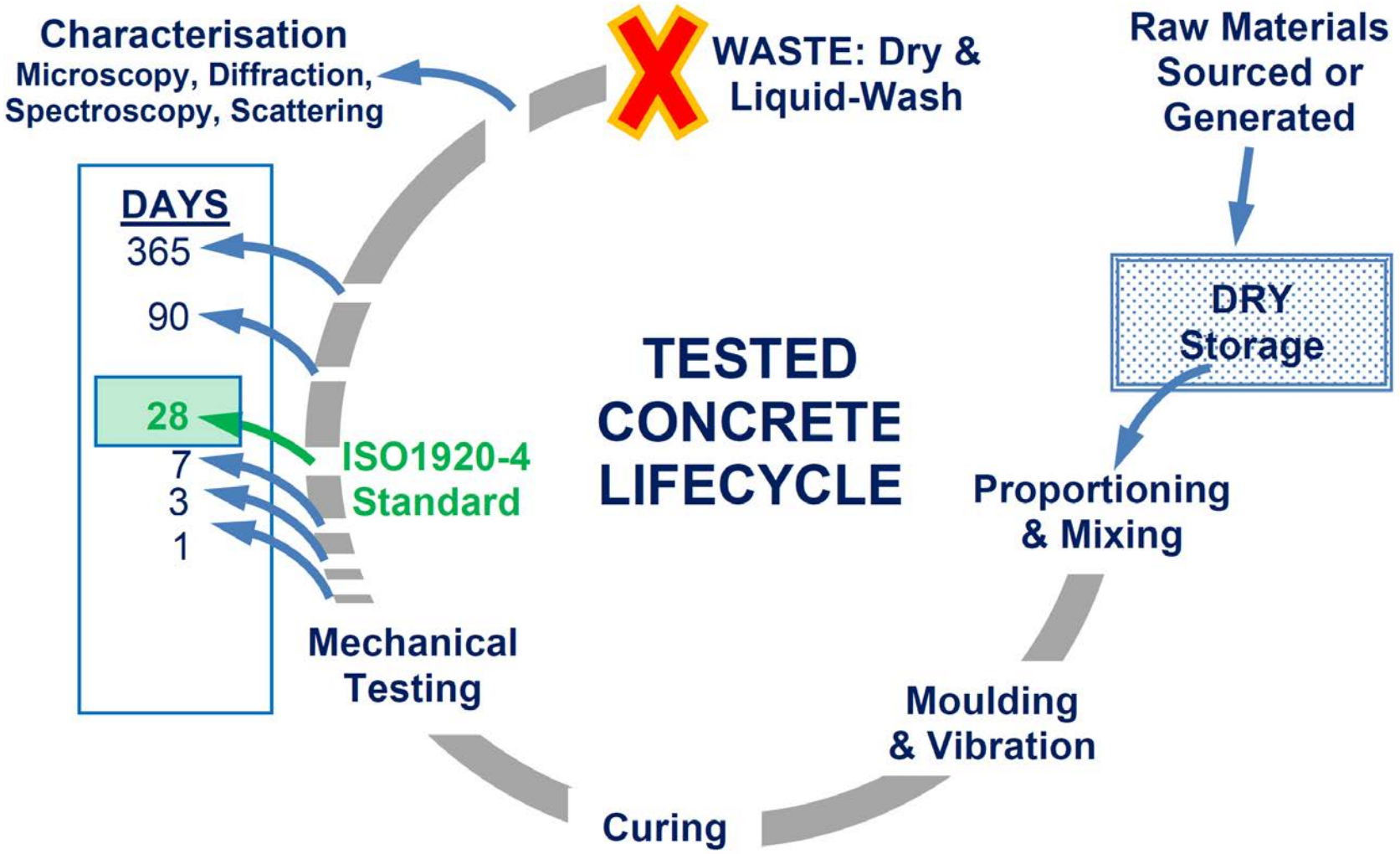
Simplification of the Complexity

'Eurocubo'
(DRC, Srl., Italy)



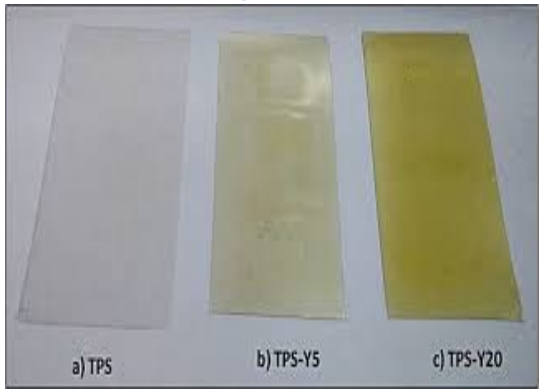
Vol=3375 cm^3 ≈ 8kg

Project Lifecycle



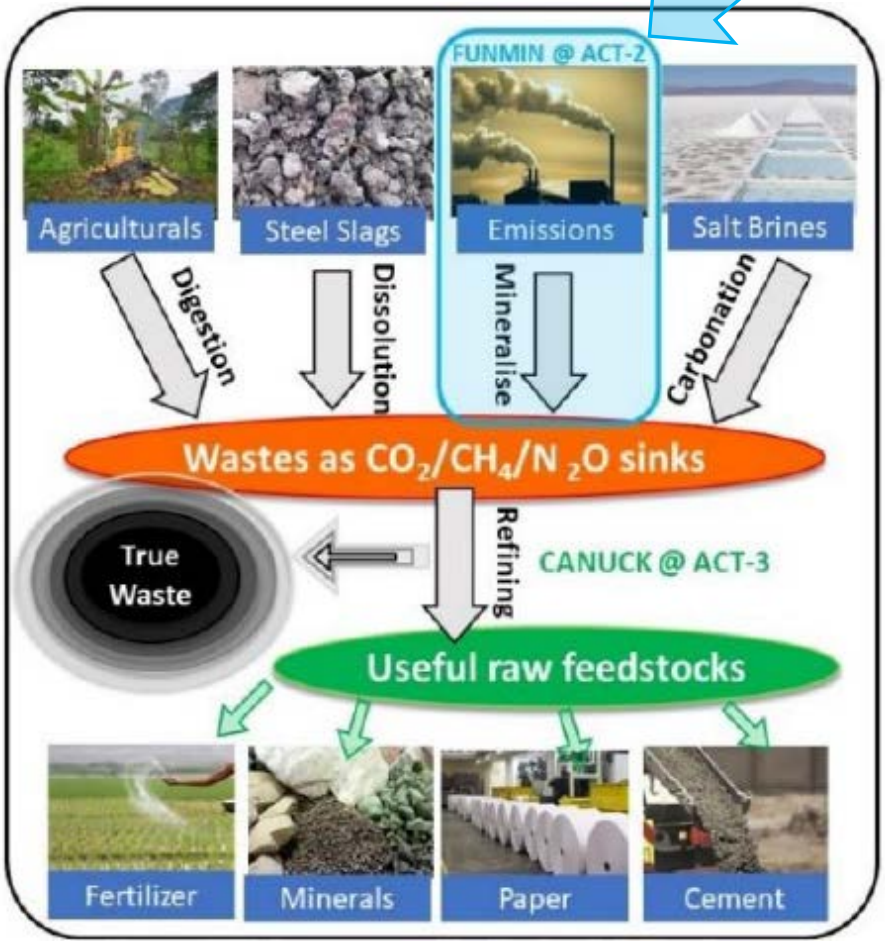
Cements: Functionality, Durability + Sustainability

UBC
McMaster University
Cambridge Carbon Capture
Sapienza Università di Roma



Agri-wastes

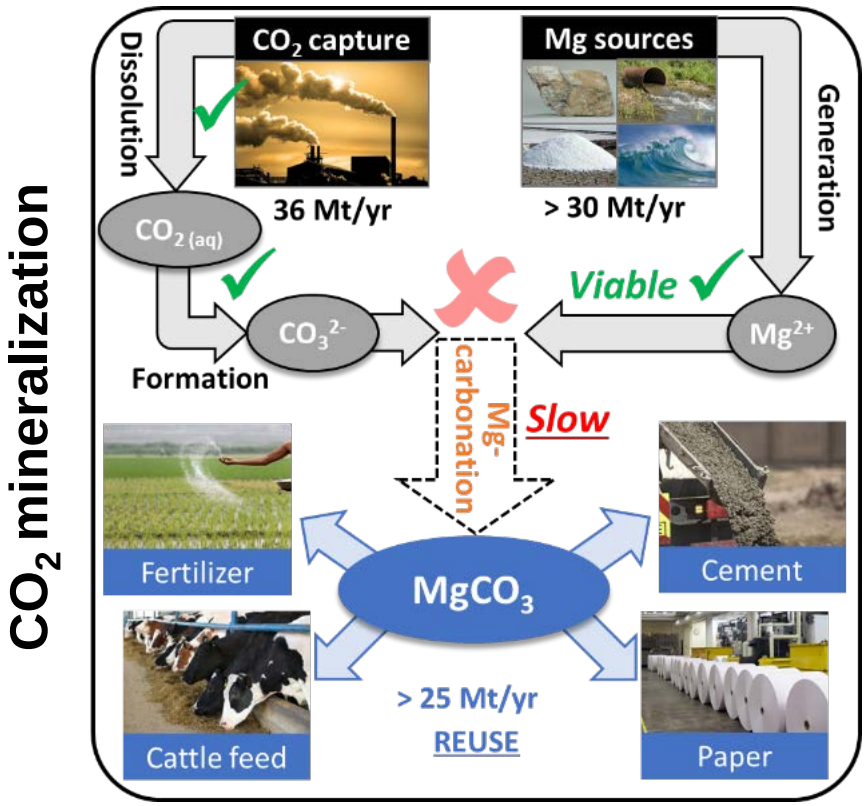
Emissions, Brines & Slags



Heritage Solutions

CO_2 – Into Added Value Products

"CCUS can create new industries and markets through the use of carbon dioxide, such as chemicals, plastics, and building materials" *



Cambridge Carbon Capture Ltd technology (**CO2LC**) to store CO_2 in mineral form ($MgCO_3$)

* The UK carbon capture, usage and storage (CCUS) deployment pathway, BEIS, 2018

Accelerating CCS Technologies

Queen Mary University of London

UNIVERSIDAD DE GRANADA

UGA Univ. Grenoble Alpes

Cambridge Carbon Capture

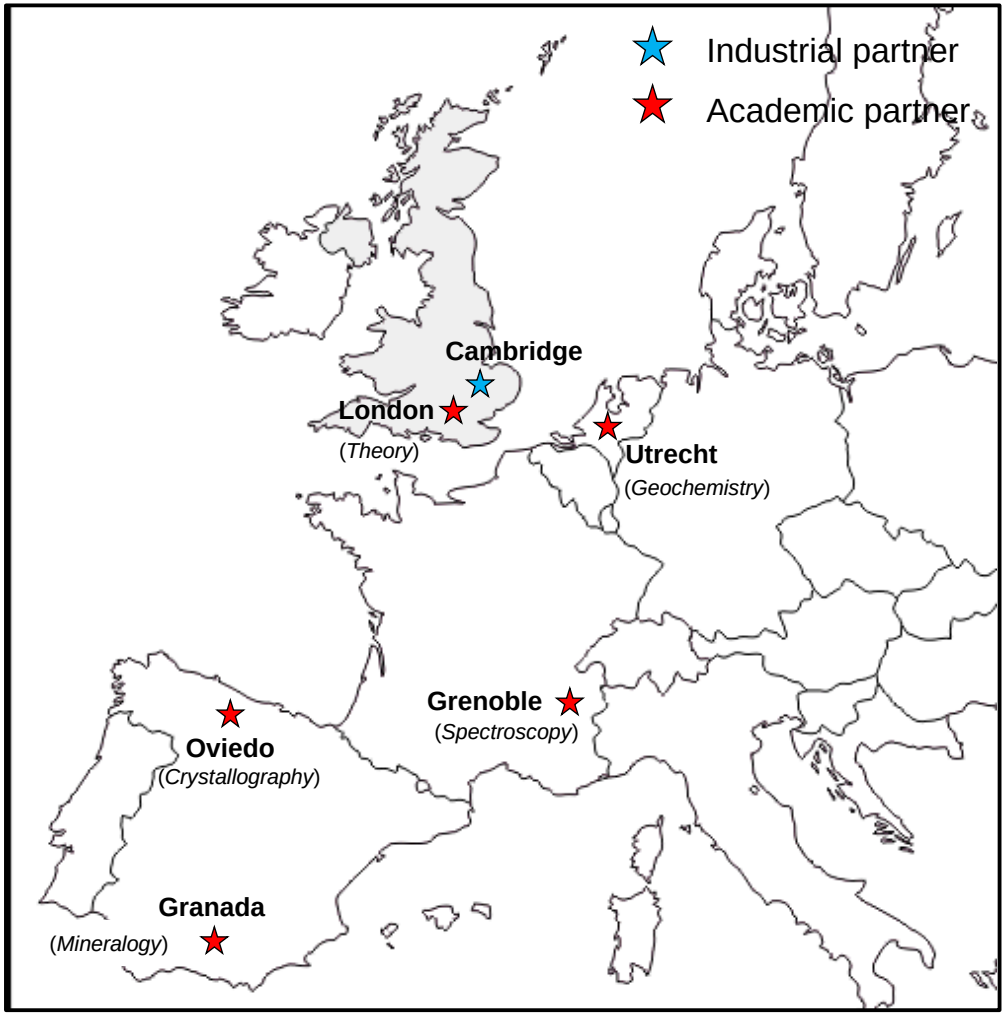
Utrecht University

Universidad de Oviedo
Universidá d'Uviéu
University of Oviedo

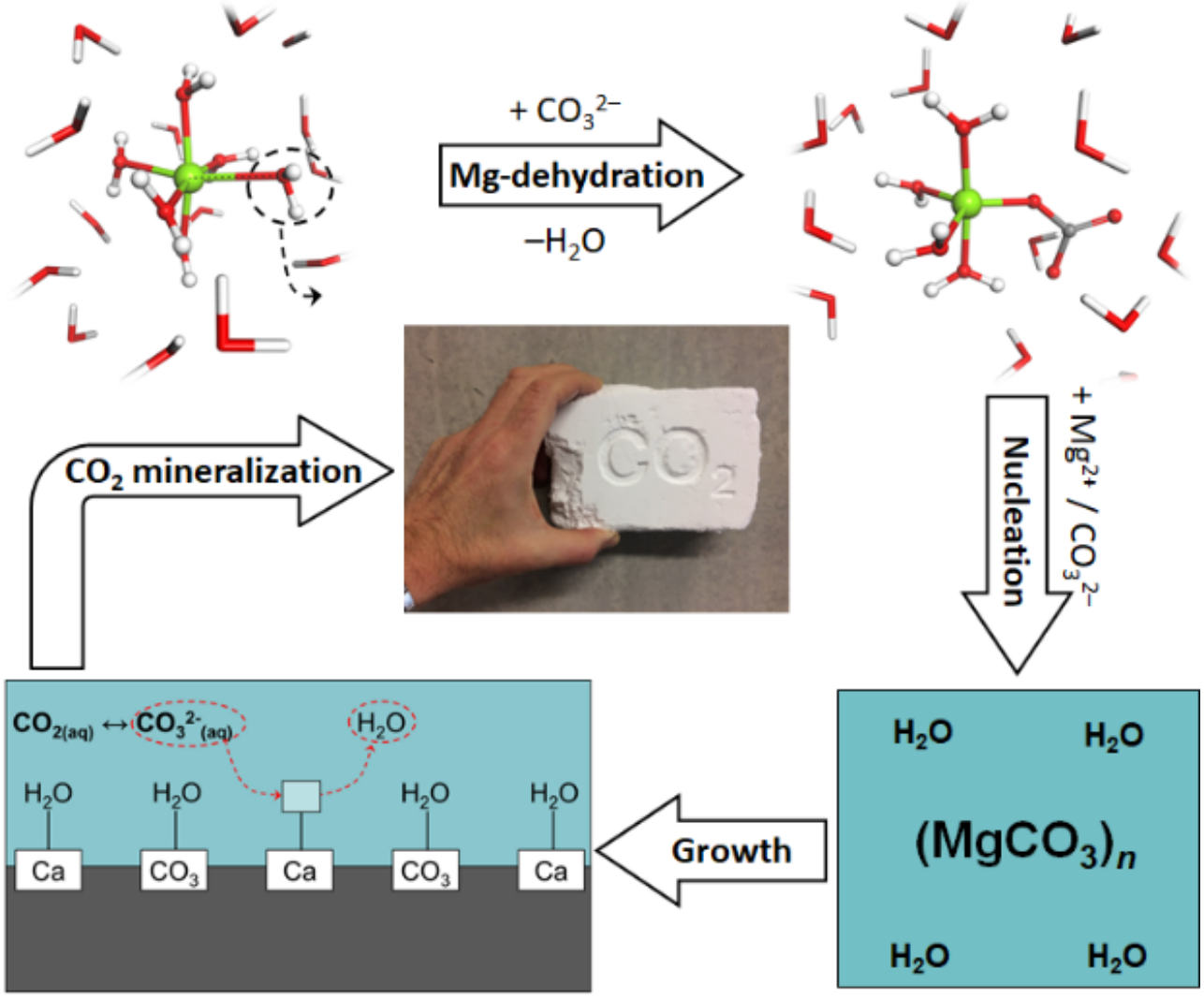
The FUNMIN consortium (EU-Horizon-2020, 902k)

World expertise in mineralization guiding Industrial technologists to permanently mineralise CO_2

$$\mathbf{CO_{2\,(gas)} \rightarrow MgCO_{3\,(solid)}}$$



Mineral carbonation



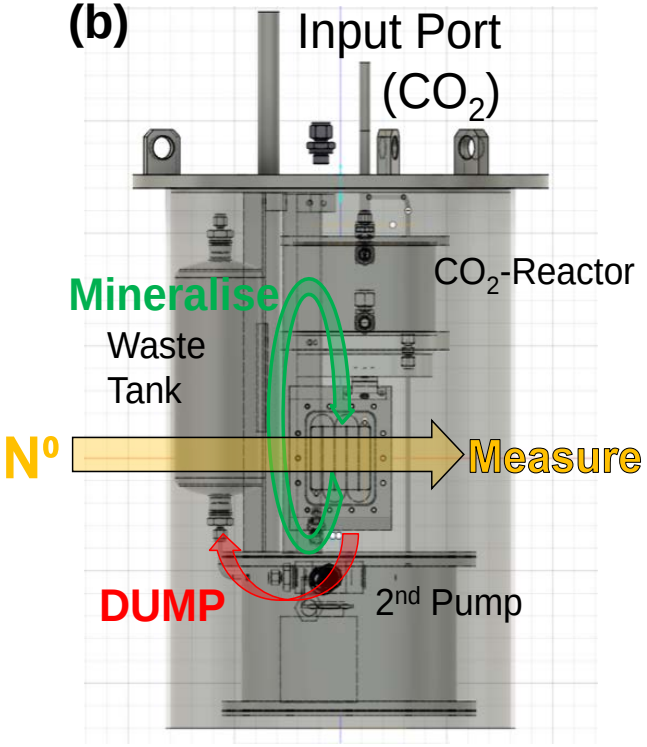
Conceptual design of a CO_2 mineralisation rig @ QMUL & RAL, UK

(a)

OBJECTIVE: reduce size and raise precision

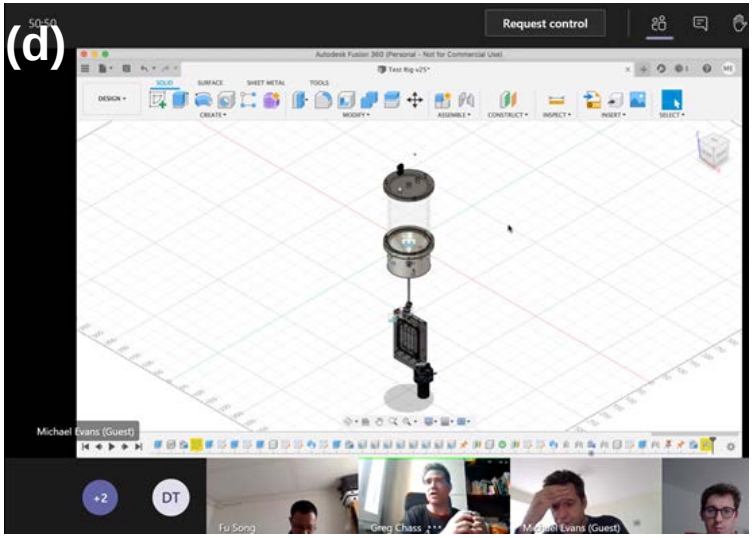
CO_2 mineralisation reactor for particle-beam measurements (i.e. neutron)

(b)



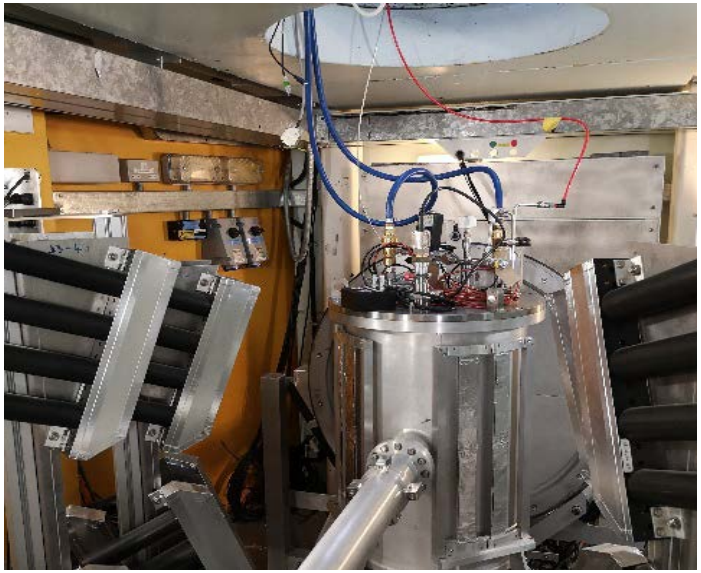
(c)

(d)

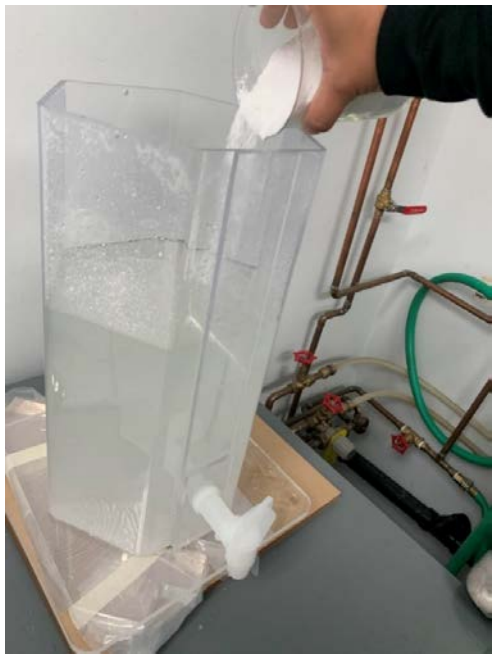


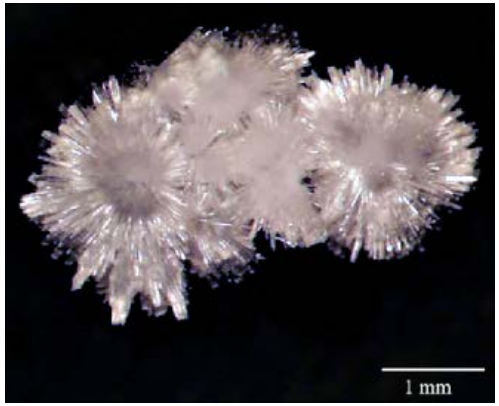
(a) Original prototype industrial reactor to track the permanent sequestering of CO_2(g) by $Mg(OH)_2$; (b) Proposed initial design of flow cell for in situ neutron scattering observation of CO_2 mineralization at the (c) UK's neutron facility. (d) 3D model and Engineering Design Specification.

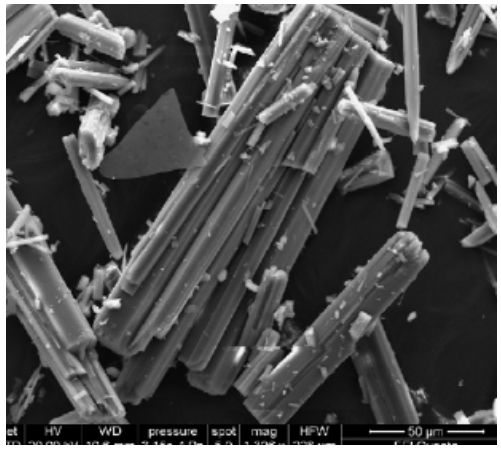
Tracking CO_2 mineralisation & toughness in real-time



BULK Mineralisations (~10kg/hr)
CO_2 mineralisation with waste industrial brine (from industry and desalination plants)

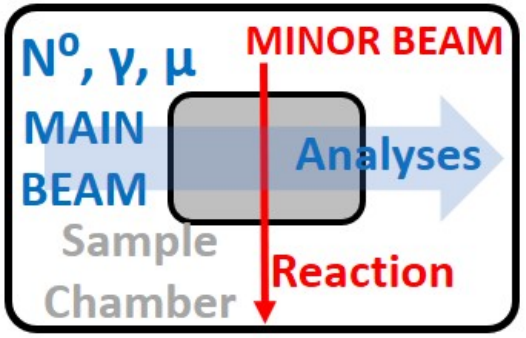


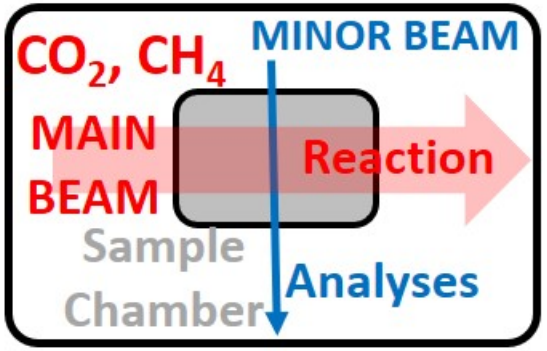




- Control $MgCO_3$ output phase & properties (amorphous ↔ fully crystalline) for use in Cd^{+2} remediation
- Proof-of-concept in-hand as additive in cement/concrete
- Scale up planned for ~50-100 kg/hr mineralisation

Beamline Mineralisation & Cementation – Nano to Bulk (widening research scope)





- **In-situ 'beamline' CO_2-mineralisations and cementation for on-the-fly analyses**
- **Nano-scale analyses on bulk-scale properties and systems**

ArcelorMittal Dofasco getting $400M from Ottawa to cut greenhouse gas emissions

CEO says changes will result in a 60% drop in CO2 emissions over the next 7 years

Saira Peesker · CBC News · Posted: Jul 30, 2021 10:43 AM ET | Last Updated: July 30

The federal government is investing $400 million to cut emissions at ArcelorMittal Dofasco.

McMaster University

The Steel Industry

- Huge CO_2 output
- Gigga-tonnes of waste ‘slags’ exist
- Locked potential in slags for use in concrete & infrastructure

Conclusions & Acknowledgements

- Wide-scope to projects will advantage their sustainability & impact
- ISO standards and project-lifecycles must be included
- Partnerships w/industry & academic partners (i.e. Canada) essential

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