Decommissionable concrete
Adsorption of radionuclides by removable bio-mineralised hydroxyapatite layers

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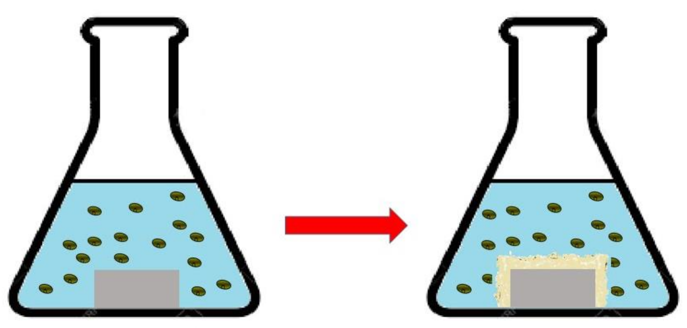
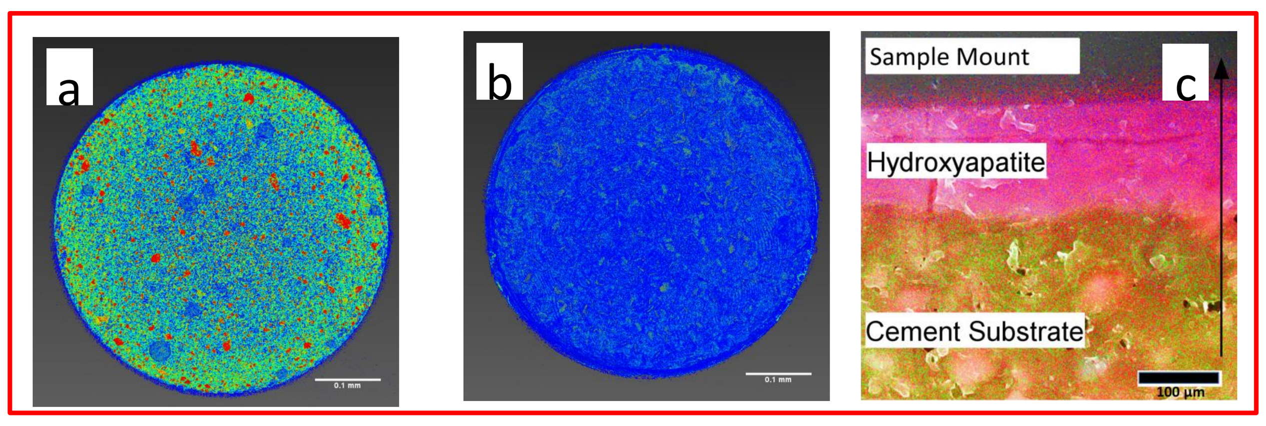
Background: The Problem

- Decommissioning of concrete infrastructure at nuclear sites can be problematic and dangerous
  - potentially high levels of radioactivity & large volumes of contaminated material
  - surface contamination ranges from mm to cm
  - can contain many radio-isotopes such as C, U, Pu, Sr & Cs
- Before decommissioning, these concrete structures must be surface decontaminated to minimize waste volumes
  - current methods include mechanical scabbling/scraping & high-pressure blasting
  - both techniques are expensive, time consuming and increases risk of contaminated particulates spreading over large areas

Decommissionable Concrete: Apatite Layers

- Microbes can form biominerals e.g. hydroxyapatite, $[Ca_{10}(PO_4)_6(OH)_2]$ (HAP, Bio-HAP), that may have higher sorption capacities for radionuclide cations than commercial HAp
- **Aim:** to develop a novel 'decommissionable concrete with a bio-mineral' (e.g. Bio-HAP) layer that enables safe, rapid decommissioning with minimal waste.
- The bio-mineral surface will be:
  - highly adsorbent for radionuclides with low permeability to reduce contamination of the bulk concrete
  - mechanically-removable from the underlying structure allowing minimal worker intervention.
- The project focuses on HAp as it can incorporate a wide range of contaminant ions within the structure[1]
  - highly promising as ion exchange/sorbent materials[2-4] for radionuclide remediation
- Bio-HAP layer was formed by incubating cement coupon in a phosphate-buffered culture of *Pseudomonas fluorescens*[5]

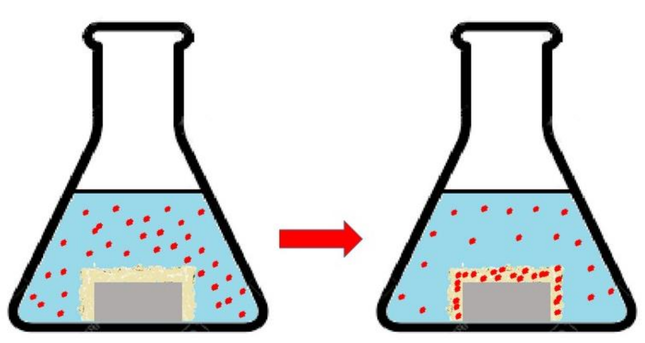




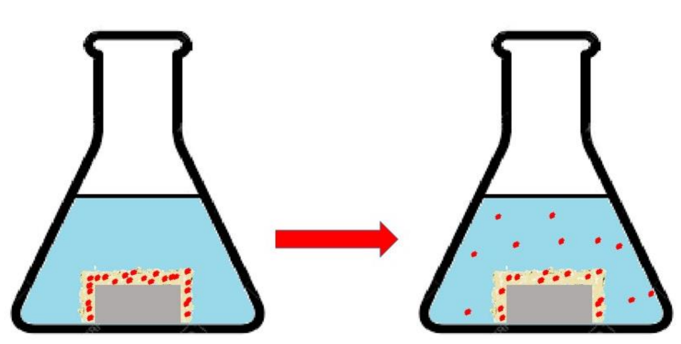
Synchrotron X-CT images of uncoated (a) and HAP-coated (b) cement samples. (c) SEM image of HAP layer

Uptake of Radionuclides: Methods

- Uptake of Sr and Cs by cement coupons coated in BioHAP or chemically synthesized HAP was investigated



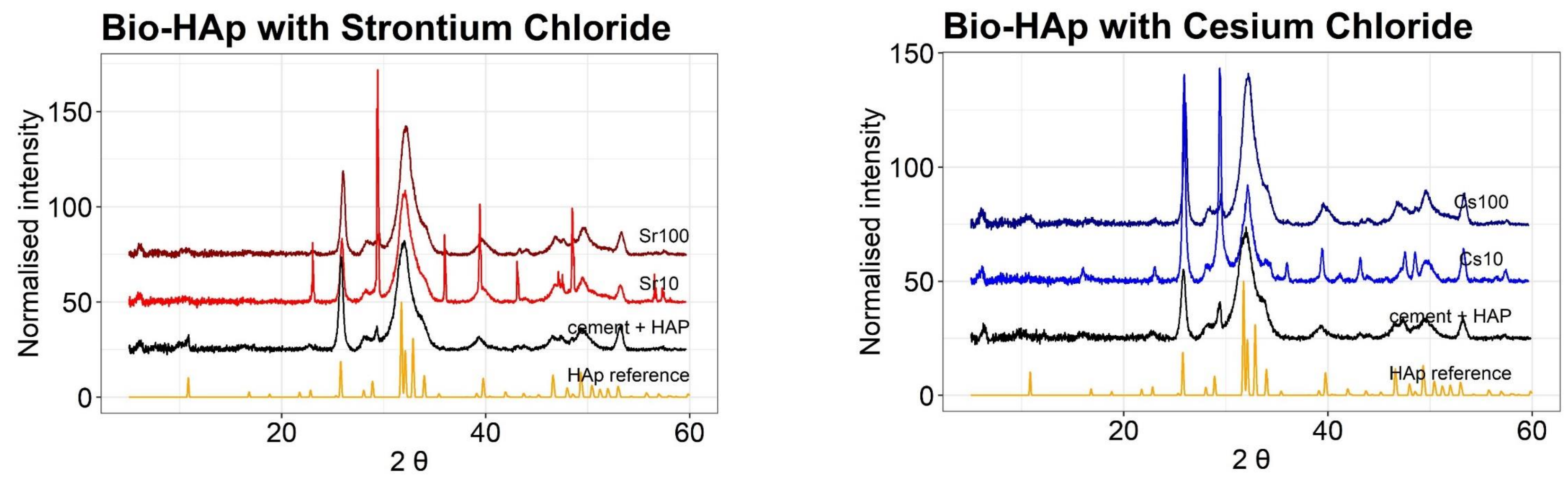
(a) Phase 1 Sorption: coated coupons soaked in $SrCl_2$ or CsCl (10 ppm, 100 ppm) for 10 days



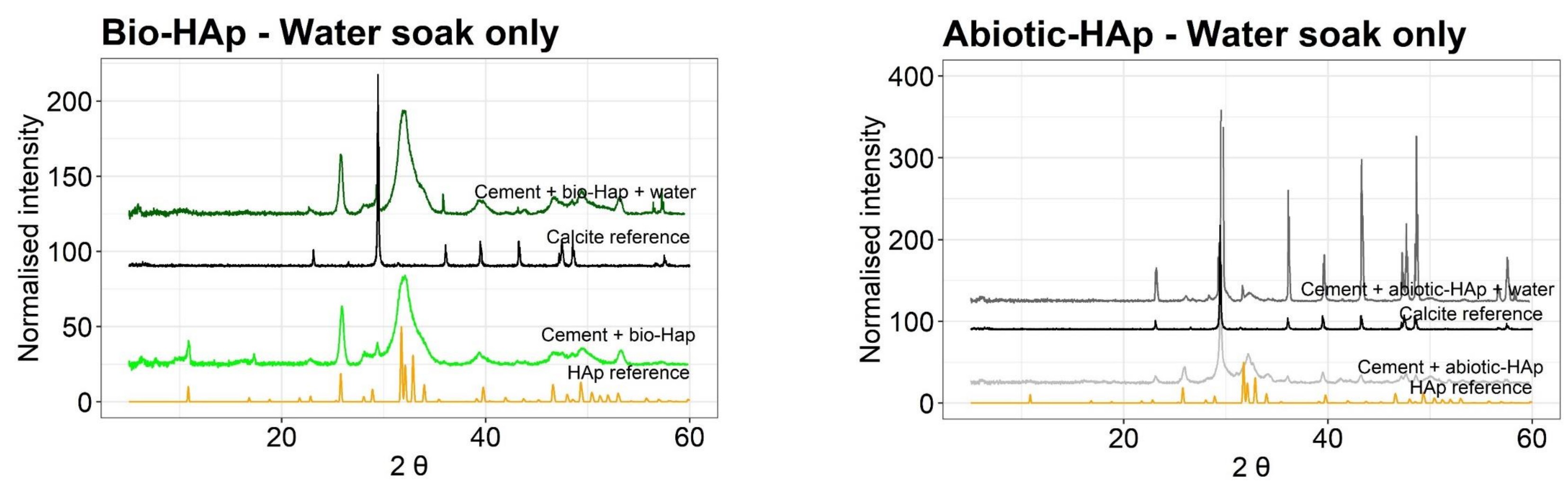
(b) Phase 2 Desorption: Sr/Cs contaminated coated coupons soaked in water for 10 days

Solutions were measured by Ion chromatography (IC). Cement surfaces were analysed using XRD.

Sorption of Sr and Cs: Preliminary Results

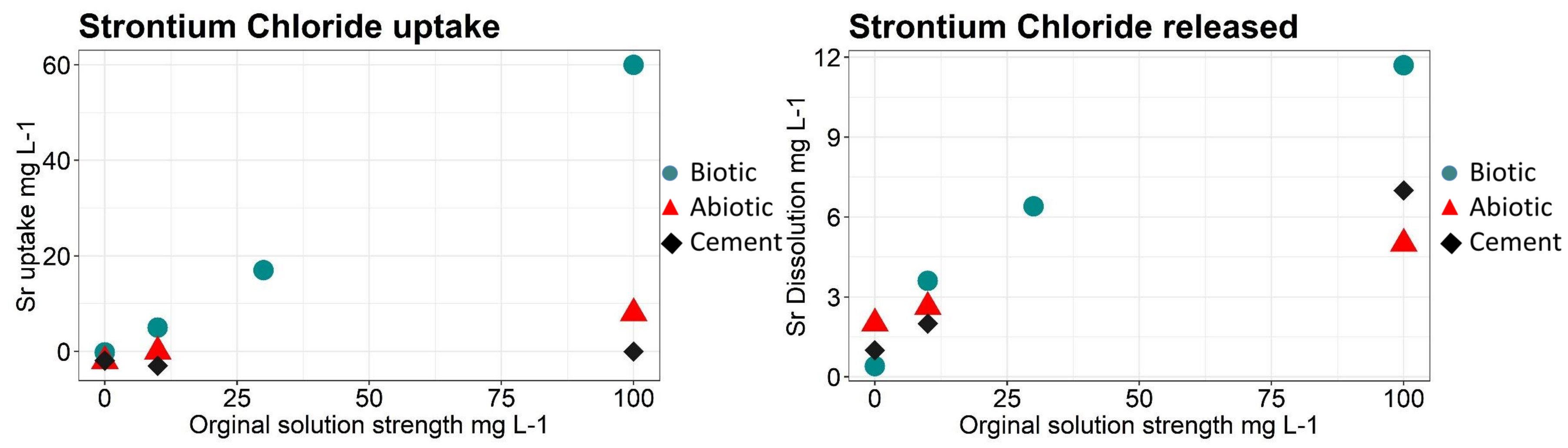


XRD patterns of the **BioHAP** cement layer before soaking (black); then soaking in either Sr (left, red) or; Cs (right, blue) in 10 ppm or 100 ppm. Gold line is the reference spectra for hydroxyapatite.

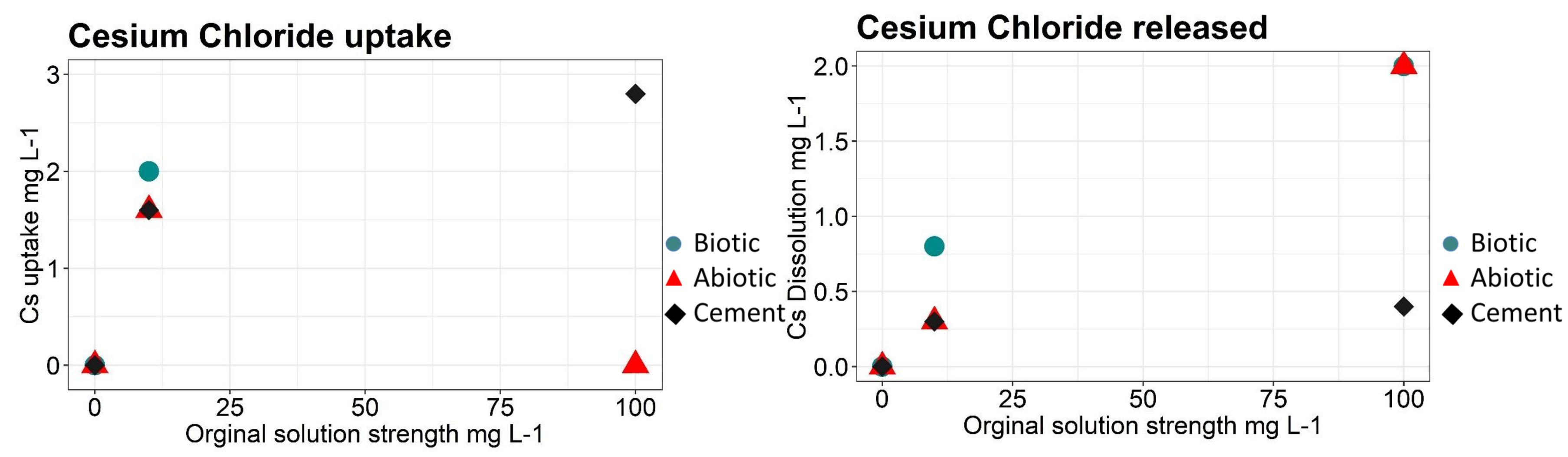


XRD patterns of the **control** sample BioHAp (left, green) verses Abiotic-HAP (right, grey) before after soaking in water. HAp reference (gold) and Calcite reference (black).

XRD results: The coupons that had been soaked in the more concentrated solutions showed less of change to calcite after soaking in water. The Bio-HAp showed greater resistance to change than the Abiotic-HAp layer.



Strontium uptake by the Bio-HAp was 60%. Greater than either Abiotic-HAp or cement only materials. **Release of strontium was variable with more Strontium released from the cement.**



Cesium uptake by the **Bio-HAp** was generally poor. Cement only showed greatest uptake of Cs. This is due to the single valence of the Cs^+ ion compared to Sr^{2+} which replaces Ca^{2+}.

Preliminary results show promise of Sr^{2+} uptake to Bio-HAp with more trials necessary at different concentrations. BioHAp also resisted Cs^+ uptake. Further investigation is required to examine the extent of ion penetration into the HAp layer and cement sublayer.

References

1. Hughes, (2015), Am. Min., 100: 1033-1039
2. Gadd & Pan, (2016), Geomicrobiol. J., 33: 175-178.
3. Handley-Sidhu et al., (2014), Env. Sci. Tech., 48: 6891-6898.
4. Rigali et al., (2016), Am. Min., 101: 2611-2619.
5. Turner et al. (2017) ACS Materials & Interfaces 9: 31401-31410

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