DEMONI - DEcommisioning Material characterizatiON and final dIsposal studies

KYT mid-term seminar 19.3.

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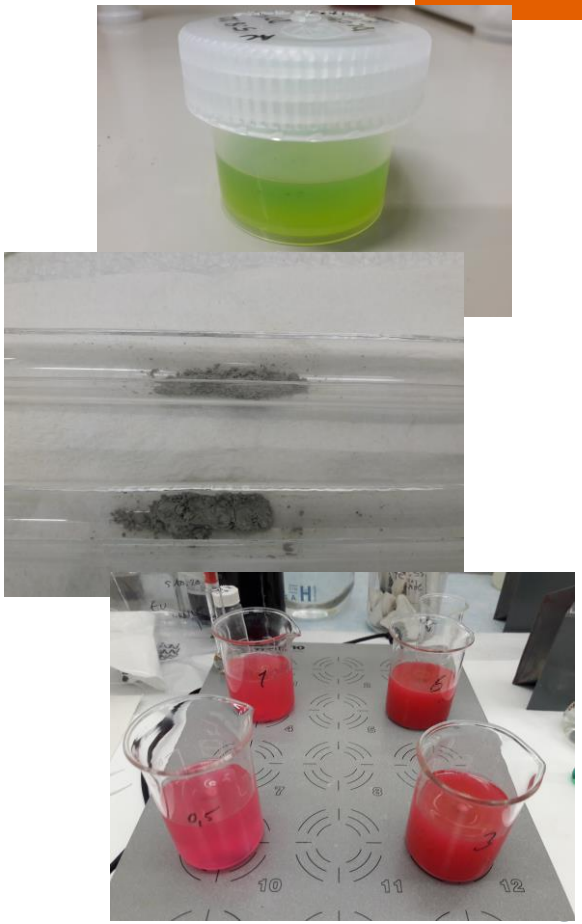
Introduction

- Focus on LLIW waste management and final disposal.
- Coordinated project between VTT and HU
  - Partially funded by NKS and EU
- Four tasks:

1) Developing activity measurement methods for difficult to measure radionuclides (DTM)
2) Effect of radiation on mechanical properties of concrete
3) Concrete leaching in simulated final disposal conditions
4) Steel leaching in simulated final disposal conditions
   - Task are connected by same samples and partially same methods
   - Activated samples of the FiR1 research reactor are utilized, but developed methods need to be universal
   - Connections to various projects KYT/TERKOR, EU/RADWASTE, SAFIR/CONAGE

Task 1: Developing activity measurement methods (½)

- Determination of nuclide vector for final disposal
- DTM method validation needed for reliable analysis and nuclide vector determination
- Radiochemical methods non-volatile DTM
  - Acid digestion – complete destruction of solid
  - Purification of DTM from each other and other interferring radionuclides
  - DTM measurement using liquid scintillation counting (LSC)
- Volatile DTMs using a Pyrolyser and LSC
- First method development, then validation via an intercomparison
  - 1st year 2019 – Activated steel
  - 2nd year 2020 – Activated concrete
  - 3rd year 2021 – Spent ion exchange resin
- Ni-59 analysis in activated steel
  - Radiochemical methods for Ni-fraction purification
  - Measurement technique development for x-ray measurements using ISOCS

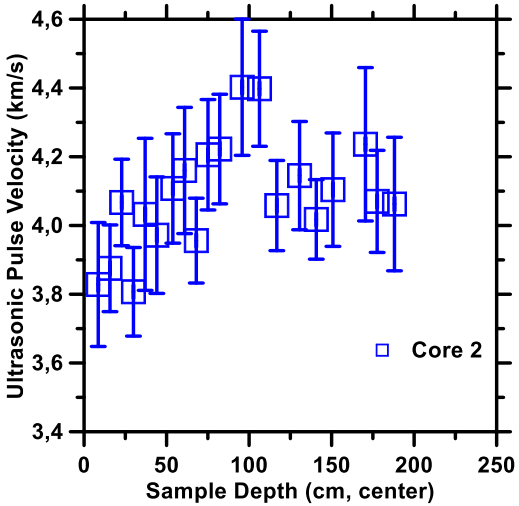


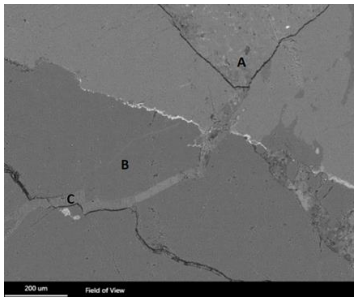
Task 1: Developing activity measurement methods (½)

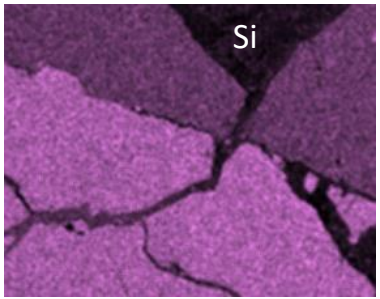
- Main results
  - Use of real materials
  - Difficult to measure, because
    - Matrix may not be soluble
    - May have significant amounts of stable elements which disturb analysis
    - May have other radionuclides which disturb analysis
    - May suffer from quenching (especially Fe-55 and Ca-41)
    - May require radiation safety conserns due to hands on radiochemical analysis
    - Etc.
- 2 NKS reports, 2 peer reviewed articles published (+2 to be submitted spring 2021)
- Collaboration with other radiochemistry laboratories is a key!
  - NKS projects in 2019-2020: VTT, HY, Fortum, Cyclife, DTU, IFE-Kjeller, IFE-Halden and self funded CEA
  - NKS project in 2021: VTT, HY, Fortum, NMBU, DTU, IFE-Kjeller, IFE-Halden and self-funded CEA, Politecnico di Milano (TBC), and Taiwan Power Company Radiation laboratory

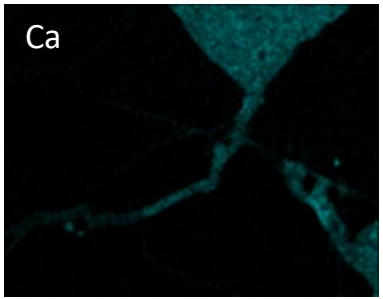
Task 2: Radiation effect on concrete mechanical properties

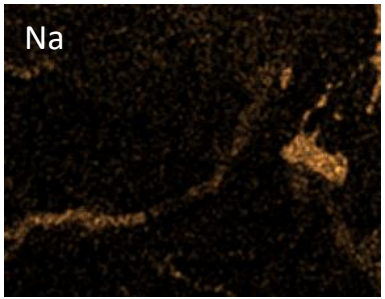
- Concrete mechanical integrity is important because changes in the concrete structure may increase the leaching rates in final disposal conditions.
- However, radiation degrades concrete's mechanical properties in many ways
- Non-destructive testing indicates a lower mechanical strength of concrete (slower ultrasound pulse velocity) in radiation-exposed concrete core
- Scanning electron microscopy shows formation of cracks within the concrete aggregates (rocks) caused by increased reactivity of Si containing material
- These results suggest that chemical changes to the concrete by radiation lead to a subsequent deterioration in its mechanical properties
- Such a finding is consistent with the focus of other projects, e.g., ACES on radiation-induced changes to long-term concrete durability





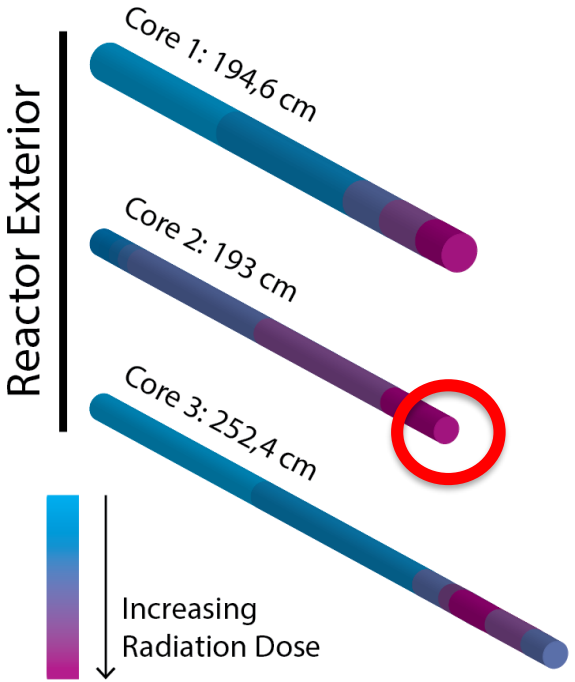






Task 3: Concrete leaching in simulated final disposal conditions

- Leaching of radionuclides or other elements from the concrete indicates its success as a physical barrier during final disposal
- Preliminary dissolution tests on active elements from the interior of Core 2 indicated minimal release of activated isotopees during first year
- However, an increase in leaching or other elements was observed
- This would likely be caused by the increased porosity and lower mechanical integrity of the concrete, indicated from Task 2
- The result suggests that further tests to account for the interaction of mechanical deterioration with leaching will better predict the concrete's ability to serve effectively as a physical barrier for safety
- In particular, exposure to moisture under leaching conditions could even promote further deterioration, and is the subject of investigations for alkali-silica reaction (ASR) durability in the SAFIR project
- ASR, in brief, is the process by which silica-rich components of concrete dissolve, and then precipitate expansive gels that cause cracking



Tasks 2 & 3: Plans for 2021-2022

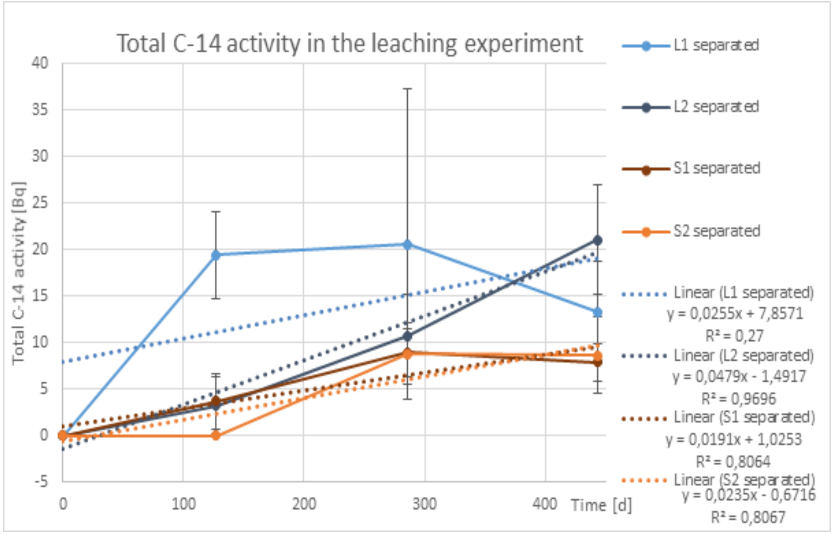
- Leaching and mechanical deterioration of concrete both influence each other
- To isolate the end result, leaching of potentially active elements through concrete, the ongoing tests will focus on two subjects:
  1. Changes in transport properties of leachable elements through concrete exposed to high radiation dose (surface leaching test, to complement dissolution tests)
  2. Changes in reactivity and mechanical stability of this concrete when exposed to high-moisture, high-temperature environments (to stimulate ASR cracking)
- Combined, these tests will help to better predict leaching rates under field conditions relevant to final disposal by accounting for both leaching and mechanical effects
- Samples from the ASR durability test will also present suitable subjects for future leaching tests, to validate models that will be developed for the coupled dissolution-leaching process in concrete when at a more advanced stage of deterioration

Task 4: Steel leaching in simulated final disposal conditions

- Determination of the release and speciation of C-14, especially the proportion of organic and inorganic C-14, in Loviisa groundwater and groundwater simulant from activated stainless steel
- Speciation of C-14 has high impact on the potential transport pathways that must be considered when assessing the migration of C-14 from the engineered system of a geological repository
- Leaching experiments in anaerobic glove box, 3 samplings 2019-2020, separation of interfering radionuclides with ion exchange, C-14 measurement with LSC and ICP-OES measurement of stable elements in leaching solution

- **Results show very low corrosion rate 0.00005 mm/a in Loviisa groundwater and 0.00003 mm/a in groundwater simulant, which result in respectively 0.02 % and 0.01 % release of the total C-14 inventory from the irradiated stainless steel piece**

- The measured activity concentrations are still low and close to the background --> uncertainties are high
- Speciation method development 2021 -->
- Connections to other projects: KYT TERKOR



Task 4: Steel leaching in simulated final disposal conditions

University of Helsinki:

- Determination of 60Co, 55Fe and 63Ni released from activated steel, 2019-2022
- Two different water types, Loviisa ground water and more salty simulant
- Dissolution data of radionuclides from decom and other waste in final disposal due to interaction with water
- Eh, pH, Gamma spectrometry (60Co), liquid scintillation counting (55Fe, 63Ni), extraction chromatography, filtration (0.2 µm)

- Differences between two waters in 60Co conc., removal of 60Co (and 55Fe&63Ni) in filtration, particle formation...
- Sampling &analysis continues in 2021-2022
- Connections to other projects: KYT "TERKOR"

BSc thesis (University of Applied Sciences) has been produced within this subtask in 2020-2021,
as well as another **BSc thesis in Task 1** in co-operation with VTT.