Final Seminar of the SAFIR2022 and KYT2022 Research Programmes 23.-24.1.2023

Project abstracts of Lumituuli meeting room in alphabetical order

SAFIR2022 - The Finnish Research Programme on Nuclear Power Plant Safety 2019 - 2022

KYT2022 - Finnish Research Programme on Nuclear Waste Management 2019 - 2022

Other abstracts can be found on the Kaleva meeting room abstracts file

ALES- Actinide Lanthanide Separation

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The ALES (Actinide Lanthanide Separation) has been run under KYT 2022 Framework Programme 3.2.1 (Nuclear Waste Management Technology) and it is a project where solid phase extraction (SPE) materials are developed for Ln / Ac separation as part of partitioning and transmutation research relevant to the advanced nuclear fuel cycle. The hypothesis of the project was met as clear evidence on the effect of tunnel size and electron acidity/basicity of the hybrids' different counterparts was observed. The possibility of tailoring the hybrids was shown and material with a higher affinity to Am than Eu was synthesized. This is the first time such behavior is reported with SPE materials. Beside the SPE-material development, one of the main goals of the project has been to train an expert in the field of the advanced nuclear fuel cycle.

BEEFS – Benchmarking and evolving earthquake fault-rupture simulations

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Finland is located on the seismically quiet Fennoscandian shield, with no modern-time observations of large earthquakes. Therefore, seismic hazard analysis is conducted with very limited observations of surface ground motions caused by earthquakes. The underground repository suffers from even lesser data availability, as no observation on underground movements caused by earthquakes exist. With developments in earthquake fault-rupture simulations, advanced software applications became available, and many publications were dedicated to simulating the rupture of earthquake faults, leading to large benchmarking exercises to compare predictions of different software. In this work we propose a more “agile” simulation methodology, by benchmarking suitable FEM/DEM codes 3DEC, FLAC3D and SEISOL. We confirm that these software codes are simulating the rupture of earthquake faults very similarly, and we compare the model preparation, run-times etc., to select the agile modeling technique for the future.

BROCTIO – Bentonite-rock interactions

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The phenomena related to the clay components (bentonite buffer and tunnel backfill) and surrounding bedrock in KBS-3 disposal concept are studied experimentally with the aim to produce information for modelling. The research topics are 1) transport phenomena at the bentonite-rock interface, 2) the effect of bedrock on bentonite mechanical behaviour, and 3) rock fracture and material characterisation. The research methods include novel use of X-ray tomography and triaxial tests to study the transport and mechanical phenomena as well as several methods for the rock fracture and material characterisation (e.g. micro XRF, XRD, and SWIR imaging). The project key results are the developed experimental research methods and processes together with detailed numerical data from the experiments, which can be used for model conceptualisation and parametrisation.

CAPSULE/BECOLT - Behaviour of Copper under Load Transients

Juhani Rantala

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The longest uniaxial creep test for Cu-OFP has been running for 19.5 years and is currently at >32% strain. This test suggests that the ductility of copper remains at a high level even after long times. Stress history dependence has been demonstrated by experiments. Testing of copper with large grain size has shown remarkable reduction of rupture time, but this might be an effect of non-representative dislocation structure produced by heat treatment. No combined effect of creep and corrosion has been observed, but the test arrangement might not have been successful. Static and cyclic relaxation testing of Cu-OFP has been carried out to produce a relaxation creep model. A MSc thesis was done on image analysis of creep cavitation in cross-weld FSW test samples. Small Punch tensile testing was applied on canister lid and tube material. This method could be effective in testing material properties on small local areas of the FSW, for example of the weld boundary.

CAPSULE/CRYCO - Validated advanced modelling and prediction of long term deformation and damage of copper

Tom Andersson

VTT Technical Research Centre of Finland

In KYT-Cryco the aim was to develop a crystal plasticity model capable of capturing the stress relaxation (creep) behavior. An finite element method crystal plasticity (CP-FEM) model was developed for estimating the relaxation behavior of oxygen free phosphorous added copper (OFP-copper). In experiment and characterization task creep-relaxation tests were performed and analyzed as well as characterized with electron microscopy techniques (mainly SEM-EBSD but also some TEM). In modeling task a few different types of models were tested and used to predict the relaxation behavior and also creep cavity formation. Creep cavity characterization and models is reported in previous year's reports. Main results for the project will be reported in the ECCC conference and conference paper.

CAPSULE/MECAN - Mechanical strength of copper canister

Sven Bossuyt, Hannu Hänninen, Patrik Sahiluoma, Ville Björklund

Aalto University

The MECAN project focuses on topics of concern for the long-term structural integrity of the copper canisters. Modern full-field measurements of the deformation behaviour were used to characterise and understand the mechanical properties and deformation mechanisms of the copper canisters and their welds, and how those relate to the microstructure and manufacturing conditions. These methods proved particularly useful for studying the localization of deformation. The effect of hydrogen on the mechanical properties was studied, with particular attention to the phenomenon of micro-void formation. Stress corrosion cracking of copper in sulphide environment and the role of oxide particles resulting from friction stir welding were studied in collaboration with the SUCCESS project.

CAPSULE/MECCI – Mechanical strength of cast iron insert

Sven Bossuyt, Hannu Hänninen, Patrik Sahiluoma, Ville Björklund, Malo Valmalle

Aalto University

The MECCI project aims to address some of the uncertainties concerning the cast iron inserts and their characteristics in the long-term. As a first step towards assessing the combined effects of blue brittleness, radiation-induced embrittlement, hydrogen embrittlement and creep, we studied strain aging and estimated the possible amount of hydrogen in the material. Due to the likelihood of stress concentration and localized deformations, the local uptake of hydrogen can be many times higher than the average of the total amount of water and metallurgical hydrogen distributed over the entire mass of the cast iron insert. The ductile cast iron material exhibits strain aging across the range of temperatures expected in the repository, and is prone to both static and dynamic strain aging after a plasticizing shear movement in the bedrock. Physical mechanisms for the different embrittlement phenomena are partly the same, so they interact non-linearly and need to be studied together to properly model the combined effects.

CAPSULE/OXCOR - The effect of oxide layer on copper corrosion in repository conditions

Jari Aromaa

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After assembly the spent fuel will cause increase in canister temperature. The canister surface will be oxidized, and the oxide film can possibly increase copper corrosion rate. The purpose of the OXCOR project was to estimate the effect of the oxide film on corrosion. The effect was studied by comparing corrosion rates of non-oxidized and oxidized samples, with approximately 100 nm Cu2O+CuO. Test environments were synthetic ground water and bentonite clay pore water purged with air or nitrogen to control the oxidizing conditions. Long-term immersion tests at room temperature showed that corrosion rates in pH = 8 ground water decrease from 20 m/y to 5 m/y in 40 months. In pH = 10 pore water the corrosion rates decreased from 5 m/y to less than 1 m/y. In short-term electrochemical tests of 3-4 weeks at temperatures 20 to 80C, the corrosion rates were 2-40 m/y in ground water and from less than 1 m/y to 7 m/y in pore water. Corrosion rates increased with temperature in both waters. Higher pH of pore water promoted passivation. Dissolved oxygen had no significant effect. Comparison between oxidized and non-oxidized samples showed that the oxide film had generally no effect on corrosion. The thin air-formed oxide film did not increase corrosion rate neither did it give long-term protection.

CAPSULE/SUCCESS - Susceptibility of CuOFP to stress corrosion cracking in sulphide containing environments

Timo Saario

VTT Techinical Research Centre of Finland

In overall the project aimed at providing an answer to the following question: Is Cu-OFP susceptible to stress corrosion cracking (SCC) in presence of sulphides?

The work in the project shows that no continuous adherent barrier-type layer is formed on Cu in sulphide solutions, thus precluding the possibility of the development of localized corrosion modes (pitting and SCC). Thus, sulphide (in concentrations from 20 to 80 mg/l) does not cause SCC in Cu-OFP base material. Furthermore, exposure of friction stir welded (FSW) Cu-OFP to sulphide solutions in the same range showed that the hydrogen concentration in FSW Cu-OFP decreases as a result of the exposure, thus precluding the possibility of hydrogen induced cracking of the FSW Cu-OFP material.

CloMap – Mapping of Closure-Related Issues in Finnish Radioactive Waste Repository Programs

Tim Schatz

VTT Technical Research Centre of Finland

The KYT CloMap study aimed to evaluate nuclear waste repository closure related obligations and their handling in Finland. In the first phase the responsible organisations were identified as The Finnish Radiation Safety Authority, Ministry of Economic Affairs and Employment, Posiva, TEM and Fortum. Twenty-five closure/post-closure requirements were assessed, and four issue categories determined. In the second phase, discussions with the responsible organisations were held to find out whether more information regarding the handling of post-closure monitoring and -knowledge preservation, transfer of ownership and post-closure responsibilities, and stakeholder engagement related obligations was available. In addition, a stakeholder survey was created on the same topics and distributed to residents of Eurajoki and Loviisa. The discussions with the responsible organisations showed that a limited amount of post-closure planning exists. The organisations are aware of their responsibilities, but detailed planning is considered to be started much nearer to repository closure. The license holders and the radiation safety authority emphasise that post-closure activities are not required for ensuring long-term safety. However, leaving such planning until facility closure may not be ideal due to possible technological gaps and loss of information during the long operational phase. Although the reach of the stakeholder survey was limited, the respondents showed interest in post-closure related topics.

ConLot - Durability Testing of Concrete in Long-Term Simulated Groundwater Conditions

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The research topics are divided into two work packages, addressing i) Literature review about the identification of concrete structure behaviour in repository conditions (WP1) and ii) Field and laboratory testing program for assessing the long-term performance of concrete structures (WP2).

The main findings for each of these work packages are:

1) WP1 – produced a literature survey about identification of the following topics: a) the behaviour of reinforced concrete structures under LILW disposal conditions, b) understating the timescales for concrete structures in LILW nuclear waste repositories, c) investigation of the factors affecting the behaviour of concrete structures in final disposal condition, d) studying the degradation mechanisms of concrete structures in final disposal condition and e) presenting the influence of cracks on the durability of concrete structures.

2) WP2 – included two tasks: (i) field testing program that was carried on for inspection of concrete specimens that are stored in different solutions in the Olkiluoto nuclear waste repository and (ii) laboratory testing program for measuring of the reinforcement steel corrosion in concrete stored in a condition of 25% sodium chloride solution at about 10°C. The field testing results show that the mechanical properties of concrete (compressive strength and modulus of elasticity) were relatively high, a mesh-like micro cracking was detected in the petrographic thin-section analysis (normal occurrence for dense concrete mixtures), the chloride content in specimens stored in groundwater was very low, and no corrosion risks were expected in that scenario and the pattern of the sulfate and magnesium content with the depth is sporadic. The laboratory measurement results show that a pitting corrosion of the reinforcement steel occurred due to the bleeding of concrete and the corrosion potential measurement results after 10 years agree with the visual inspection of the corrosion status

DEMONI - DEcommisioning Material characterizatiON and final dIsposal studies

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DEMONI is a coordinated project between VTT and Helsinki University Department of Chemistry. The aim of the project is to develop and validate activity measurement methods and to perform leaching rate tests to study different long-term phenomena in low- and intermediate level decommissioning waste. Four different tasks are interconnected by same sample materials, so that the measurement activity data can be utilized in the final disposal simulation tests. Samples have been collected from the FiR1 research reactor under decommissioning and partially from Finnish nuclear power plants. Having samples from real nuclear facilities has been extremely important to be able to take into account practical problems, which are not typically present when using only laboratory standards.

During years 2019-2023 the project results have been reported in 1 MSc thesis, 2 Bachelor theses, 9 peer-reviewed scientific articles and 15 conference presentations of other technical reports. Obtained method development enables fluent activity measurements for future decommissioning projects, replies to concerns related to the effects of radiation on mechanical effects of nuclear waste and provides data on differences of radionuclide leaching rates in real ground water versus chemically simulated leaching water.

FENIX - Reactor Pressure Vessel Repair Welding Collaboration

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As nuclear power plants age, it becomes more necessary to repair safety-critical components that are difficult to replace such as the reactor pressure vessel. The reactor pressure vessel repair weld scenario is studied in the project by produc-tion of a mock-up with two surface excavations that were filled with repair weld-ing with automated gas metal arc welding (GMAW) using cold metal transfer (CMT). Two different bead patterns, a conventional 0-degree welding direction and a 45-degree hatch pattern were used to optimize the residual stress state. No clear differences in the weld microstructure and fusion boundary were ob-served using SEM, EBSD and EDS between the two welds. The microhardness measurements indicated higher fusion boundary hardness in the 0-degree welding direction sample, but the indentation hardness measurements did not show any such differences. The measured residual stress profiles were similar for both welding patterns. Overall, the research showed that GMAW-CMT is a promising technique to perform surface repairs, due to its easy automation, good weld quality and stable arc and low heat input leading to a narrow heat affected zone, but the observation of both porosity and lack of inter-run fusion between weld beads indicated that there is a need to further optimize the weld-ing parameters.

KAMU - The influence of chemical conditions on gas generation in the disposal of low level maintenance waste

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A large-scale Gas generation experiment (GGE) was established in 1997 in Olkiluoto, Finland, to simulate the gas generation from low-level maintenance waste under repository conditions. The GGE is operated by TVO and has been monitored for generated gas, water chemistry and microbiology. Gas generation started during the first year of the GGE as result of microbial degradation of waste and steel corrosion. The aim of the KaMu project was to induce disturbances to the GGE and study the impacts on gas generation and gas composition. The addition of sulphate simulated sulphate-rich flow of groundwater through the repository and the higher pH value the influence of concrete in the repository. The main conclusion from KaMu project was that gas generation in the GGE remained stable and neither the addition of sulphate nor the increased pH did influence gas generation rate. The obtained results can be used to improve the understanding of gas generation processes and thus support the safety cases of the final disposal of low-level radioactive waste in Finland.

KARIKKO – Bedrock fracturing

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Geological Survey of Finland GTK

The aim of KYT KARIKKO was to mitigate uncertainties related to 3D and DFN (Discrete Fracture Network) modelling of brittle structures (fractures and faults). Successful development of novel methods for both mapping and analyzing brittle structural data enabled the collection, and subsequent analysis of new multiscale brittle datasets from large areas of southern Finland. Thereby, KYT KARIKKO provided new regional perspectives for understanding the inherent uncertainties related to the multiscale datasets used in DFN and 3D modelling in Olkiluoto. In addition, the project provided a better understanding regarding the complex brittle tectonic development and consequent brittle properties of the bedrock within southern Finland. Altogether, the KYT KARIKKO project contributed towards more accurate modelling of the brittle structures, enhancing a better safety for the primary barrier for nuclear waste, the bedrock barrier.

KÄRÄHDE - Spent fuel characterization and source term

Pauli Juutilainen

VTT Technical Research Centre of Finland

Safe and economic spent nuclear fuel (SNF) management requires profound knowledge of the nuclide concentrations in SNF. The concentrations as such and the resulting properties, such as decay heat and neutron and photon emission rates, affect the safety margins related to storage, transportation and final disposal of SNF. Such knowledge practically relies on computational analyses whose accuracy is affected by various uncertainties as well as modelling assumptions and approximations. The significance of these factors has been studied in KÄRÄHDE from various perspectives, mostly using the Serpent Monte Carlo code as the reference computing tool. The nuclear data uncertainties comprise the main source of uncertainty – and the main challenge with respect to the computing capacity. Instead, the choice of computational parameters and approximations of the irradiation history in the burnup calculation were found to be rather negligible in the long-term storage, although somewhat significant within a few years after the end of irradiation. Fuel and reactor type had a minor impact. However, no sensitivity analysis was included to determine the impact of the discovered variance in source term properties on the outcome of any subsequent analyses taking the source term as input.

MIRA 3-D – 3D modelling of micro structures

Pietari Skyttä

University of Turku

MIRA-3D –project focused on characterizing the mechanical discontinuities (fractures) in crystalline rocks at the scales of 10 µm to 5 cm. These fractures occur most frequently within faults and their associated damage zones, and profoundly contribute to the stability of, and fluid flow properties with the bedrock. As an outcome of the project, we developed a 3D-grinder tool for imaging the fractures within deformed rocks, and this novel tool allows imaging such fractures which are not presently open but have mineral infills (healed fractures). As such, the tool can recognize features which may not be imaged CT-microtomographic methods. Correlated with observations at m to dm scale, from the associated KARIKKO project, we found that the geometrical attitudes and topological properties between the fractures are largely the same in variable scales. Slip along the main displacement zones and parallel fractures within faults generates most continuous fractures, while the shorter secondary wing-cracks abut the slip surfaces. These together form the fracture network that promotes the generation of fault-parallel fluid flow networks. Evidence for localized fluid flow within the network (much before present-day) is available as mineral alteration of the rapakivi samples which is spatially associated with the wing-crack fractures.

MoToPro - Multibarrier System Performance - Microbiological and Chemical Processes

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The aim of MoToPro project was to gain new knowledge on the microbial influence on the multi-barrier system performance in the geological disposal of high-level nuclear waste. The results showed that in conditions simulating the disposal site, microorganisms reduced all structural iron in bentonite (in slurry to speed up the microbial reactions for the project time scale) which has significant effects on bentonite swelling ability. The experiments performed in microcosms at in-situ pressure also indicated that pressure influenced microbial community structures, and this should be evaluated in future studies. Formation of corrosive compounds at varying environmental conditions and elemental concentrations were also investigated at field sites. Accumulation of hydrogen was strongest in environments where iron hydration reactions are present, and weakest where sulfate was abundant. Sulfide formation rate increases with increasing sulfate concentration, but sulfide accumulation requires continuous sulfate supply for which bentonite is a source

NAT-LAB-14C - Using volcanic-geothermal fields to investigate transfer of deep geological C sources into terrestrial food webs

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Radiocarbon (C-14) has been recognized, both at national and international level, as an important radionuclide for safety assessment studies associated with operational discharges as well as radioactive waste disposal. Despite advances in research, knowledge on 14C cycling and potential uptake of 14C derived from belowground sources into the biosphere, particularly plants, remain inconclusive, and methodological challenges remain. In NAT-LAB-14C we utilized used a site with active volcanos where CO2 and CH4 escapes from geothermal fluids and where the C forms released are characterized by a very specific C isotope signature differing from that in plants and aboveground air. The site functions thus as a unique natural analogue simulating long- and short-term accidental and operational release of 14C (continuously, in situ). We found that the uptake of 14C into plants is highly variable among species, and ranges between 0 and 15%. In leaves of Ranunculus sp., a herbal species, 15% of soil-derived C was found, which exceeds by far the commonly known uptake rates of soil-derived carbon in plants. Since also trees were enriched with carbon stemming from belowground sources, contamination of forest vegetations could be significant in case of accidental or operational release of 14C from nuclear waste deposits. This must be considered in risk assessment models. We also found that CH4 is oxidized to CO2 in nearly all the plots, but not fully when CH4 emissions are very high. There, significant 13CH4 emissions were detected. Thus, even in arable soils the assumption that all CH4 is transformed to CO2 is not valid. Current 14C assessment models may thus overestimate the transfer of 13C from belowground sources into the biosphere and are unnecessarily pessimistic in that they assume that all 14C is released as 14CO2 and thus available for plant uptake. Through our study, a broader experimental basis and a better understanding of the release and fate of 14C in the biosphere for environmental risk assessment of nuclear waste management is provided. In NAT-LAB-14C, we also use the experimental data gained to develop a 14C compartment model in the Ecolego software (WP4) to simulate and predict risks associated with 14C release from nuclear waste disposal facilities, activities which are still ongoing. The study has a high impact on the development of radioecology in Finland at an internationally high level.

RABIO – Improved Radioecology for Biosphere Modelling

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Aim of the project was to provide data and improve radioecological modelling in aquatic ecosystems of Finland and other boreal regions. The produced knowledge will benefit the environmental risk assessment of, for example, the nuclear waste management and mining actions. The project consisted of three subprojects: 1) Transfer of elements from sediment to aquatic food chain Subproject, 2) Transfer of 14C from sediments to aquatic food chain, and 3) Improvement of radioecological modelling. The first two subprojects tested the assumption of constant concentration ratio of radionuclides between organisms and their environment with varying environmental concentrations. In addition, the roles of water and sediment as sources of radionuclide transport in aquatic food chains was studied. The third one focuses on the questions if and how the empirical observations should be considered in radioecological modelling. Analysis of the data and results of the modelling are still ongoing. However, there are indications, for example, that sediment in comparison to (pore) water should be considered as an important source for radionuclides into aquatic food chains.

RACOON - Non-destructive examination of NPP primary circuit components and reliability of inspection

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The project included studies relating to nondestructive evaluation (NDE).

NDE reliability was studied using virtual round robins (VRRs). The virtual round robin was a novel approach developed during the project, which enabled quantitative evaluation of NDE reliability in terms of probability of detection (POD) in the nuclear industry. The previous difficulties with POD evaluations and round robins were solved with the use of virtual flaws. Two virtual round robins were completed during the project and highlighted some important issues with NDE reliability in the challenging inspections of dissimilar metal welds.

Ultrasonic simulation was studied to enable more realistic ultrasound re-sponses from difficult flaws to be simulated for use as virtual data or in AI/ML training. While marked advances were made, realistic ultrasonic simulation still requires further study and especially the computational burden associated with simulating 3D defects is still excessive.

Nonlinear ultrasonic techniques were studied to improve characterization of tight or closed cracks. Cracks were measured under varying thermal loading and compared with computational estimates of crack closure.

The applicability and reliability of machine learning in evaluating ultrasonic data was studied. Machine learning (ML) models were developed and trained to detect flaws in complex ultrasonic data. The results were compared with human performance. The results showed, that ML can reach human level performance in wide range of nuclear inspection cases and data-sets.

Finally, the ML results were compared with human responses collected in the second virtual round robin. Due to it's consistency, the ML gave the best overall results in the VRR and showed that the use of ML as an aide to the inspector can help address some of the performance issues revealed by the VRR results.

RAKKA - Water conductivity of fractured rock mass

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The goal of the RAKKA research project was to determine the fluid flow characteristics of rock fractures by means of photogrammetry and using mechanical and coupled hydromechanical numerical modeling. The research project produced three new research methods, first of which is a three-way fluid flow laboratory measurement for rock fractures under constant normal pressure. The second method is the non-destructive measurement of the surface geometry of the rock fractures using photogrammetry. The third method is numerical modelling based prediction of the fluid flow properties of fractures based on the fracture geometry. The research results will benefit end-users who perform hydromechanical modeling of the rock, and in the long-term end-users who evaluate the safety of nuclear waste management, and the planning work of end-users who conduct nuclear waste management. The research results enable the determination of fluid flow properties of rock joints using photogrammetry and coupled hydromechanical numerical modeling. The results can be used to determine the fluid flow properties of the rock mass for numerical modeling software at the scale of the entire disposal area.

RASK – IN SITU – investigations: Radionuclide mobility in the cement-rock interface

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In nuclear waste repositories that will contain concrete structures in contact with bedrock, the largest uncertainties in the repository safety assessments are related to the behaviour of radionuclides with small or poorly known retention, such as C-14, Cl-36 and I-129. The RASK-project set out therefore to characterise the retention and diffusion behaviour of such radionuclides and investigate possible structural and mineralogical changes caused by long contact time between rock and concrete. During the course of the project, the retention behaviour of several radionuclides were investigated and methods were developed to measure their effective diffusion coefficients and distribution coefficients via autoradiography. Methods were also developed to characterise the microstructure and porosity of fine-grained material phases via autoradiography and STED nanoscopy. The characterisation of in situ rock-concrete interface showed that crystalline rock appears stable against alkaline conditions, while concrete is slightly degraded during long contact. The increased understanding produced by this work will lessen the conservatism in the safety assessment of the multi-barrier system and help select suitable cementitious materials. Methodologies developed during this project can be fully applied to study of near surface repository systems for LLW.

SAMPO - Safety criteria and improved ageing management research for polymer components exposed to thermal-radiative environments

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Polymer based components are applied in several parts of nuclear power plants, e.g. cables, sealants, paint coatings and lubricants to name a few. During their use they are subjected to ageing. In this project several polymer ageing related subjects are researched.

The lifetime of several components from nuclear power plants was estimated with traditional accelerated aging which may help to adjust exchange intervals and acceptance criteria for EPDM O-rings were established. In addition, iso-thermal micorcaolrimetry was used to estimate the activation energy and several dielectric methods were tested for condition monitoring of polymer components.

Development of condition monitoring methods was performed with several methods. It was shown that thermogravimetric analysis (TGA) can be used to evaluate the filler content of the polymers which helps defining differences in material quality between material batches. Computational models that help to process non-destructively measured data and predict antioxidant consumption in materials were developed.

SURFACE - Near Surface Repositories in Finland

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KYT2022 project SURFACE "Near Surface Disposal in Finland" started in 2019 with the objective of studying the applicability of near surface disposal of VLLW in Finland. The first report published in 2020 discussed regulations and guidelines, safety case considerations, different near surface disposal concepts, and Finnish site conditions with expected changes due to climate change. The remaining 3 years concentrated on scoping the performance of a landfill-type near surface disposal facility. Work included studies on 1) radionuclide transport behaviour in barrier materials by University of Helsinki and VTT, 2) biodegradation of waste and steel corrosion by VTT, and 3) performance of the disposal facility and EBS by VTT. In general, the facility shall be designed considering near surface processes prevailing during the next ~300 years, evolution of the waste and EBS, and site characteristics affecting radionuclide transportation.

TERKOR - Corrosion of low and intermediate level steel wastes under in-situ disposal conditions

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The TERKOR project studied the corrosion performance of carbon steel, pressure vessel steel and stainless steels in conditions simulating in-situ repository conditions. The materials were exposed to natural groundwaters with microbial additions in a series of five experiments across which the materials' behaviours were monitored and characterised to observe the effect of microbial communities, different waters and steel activation on the corrosion rates, corrosion products and microbiology. The presence of microbes and varying microbial community composition were found to lead to differences in the corrosion outcome. Moreover, local groundwater conditions affecting the chemical and biological properties of the water had an influence on the corrosion tendency of the material. The results of TERKOR support the decisions to be made concerning the decommissioning of metallic components, and the repository of the low and intermediate level waste produced during operation.

YLYMU - Final disposal of spent nuclear fuel and societal memory

Petri Paju

University of Turku

This study explored the views of Finnish nuclear waste management experts on preserving knowledge of the final disposal facility, as well as previous discussions on the topic in Finland. Current experts saw the theme of knowledge preservation becoming more broadly relevant as the closure of the final disposal facilities approaches which will take place many decades from now. The licensee Posiva Oy considers that it is sufficient to landscape the site of the final disposal repository while the State preserves the knowledge permanently. In Finland, they have documented few discussions about knowledge preservation. However, the study identified some early Finnish debate on far future social memory issues, including the possible use of markers, and more recent, critical contributions by artists. Overall, studies by Nuclear Energy Agency suggest that knowledge preservation should be considered more urgent than most Finnish experts and actors perceive at present. One recommended step forward is to follow and discuss knowledge preservation in ONKALO's Periodic Safety Review process.