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Perspective

Repositories for Heat Producing Nuclear Waste – Behaviour of Bentonite at Higher Temperature

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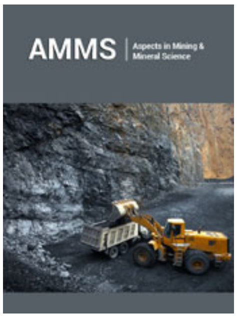

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Perspective

High level heat producing radioactive waste is generally planned to be disposed of in deep geological repositories, which contain and isolate the waste from the biosphere. The repository typically comprises multi-barrier system: the natural geological barrier provided by the repository host rock and its surroundings and an Engineered Barrier System (EBS). An essential component of EBS typically is some clay-based material, often bentonite, which has many beneficial properties like very low permeability, high sorption capacity and swelling/ self-sealing capacity. Bentonite is applied as buffer between the bedrock and waste canister. Bentonite has been studied for decades in nuclear waste community. These studies have included diffusion and sorption of radionuclides, transport of water and gases, heat transport and chemical, mineralogical, and mechanical behaviour. The last topic, mechanical behaviour focusing especially on swelling and swelling stress formation, has developed during the years from relatively simple models to very complex computer models. However, the modelling in the case of bentonite cannot be only based on known chemistry and physics but includes many phenomenological topics like constitutive equations coupling different variables – these equations must be studied and fitted empirically [1]. In most repository concepts the highest temperature has been limited to 100 °C or less, and that is the reason for limited mechanical understanding at elevated temperatures 90–150 °C. Over 150 °C causes mineralogical changes, which can be detrimental for buffer [1] and therefore kind of upper limit for long term disposal (thousands of years).

HITEC is a Workpackage in EJP EURAD Project (European Joint Programming on Radioactive Waste Management, HORIZON 2020). HITEC studies both clay host rock and bentonite buffer, the second one being the topic in this presentation. HITEC background is that proving higher temperatures than presently accepted suitable is very relevant for optimizing the size of the repository and whole disposal route i.e, interim storage time. This is true even for current concepts: it increases safety margin and gives greater credibility to the design e.g., if it is proven to work for 130 °C then for 100 °C it is definitely safe from the point view of temperature. The overall objective is to evaluate whether an increase of temperature is feasible and safe by applying existing and within the HITEC work package produced novel knowledge about the behaviour of clay materials at elevated temperatures. HITEC aims to improve understanding of the THM (Thermo-Hydro-Mechanical) behaviour of engineered clay material (buffer) under high temperature and provide suitable THM models both for buffer, to identify processes at high temperature and the impact of high temperature on the THM properties of the buffer material. The final aim is to document all the above to be utilized in Safety Cases studies. HITEC studies mostly mechanical behaviour of bentonite at elevated temperatures. These studies are carried out in three different ways. First, analysing heat treated bentonite properties and compare these to non-treated ones. Second, measuring bentonite properties at elevated temperature. Third, carrying out experiments at high temperature and modelling the results.

The experimental methods utilized are mechanical experiments in different setups, swelling and permeability tests mostly in lab scale at elevated temperatures. The measurements at high temperature include tress, deformation, hydraulic conductivity and temperature. These experiments are complemented by X-ray and neutron tomography. The modelling is carried out and developed by different methods to enable comparison between different approaches. The first results this far are the methods to carry out experiments at higher temperatures so that the required measurements including tomography can be done. As an example, for Czech BCV bentonite treated dry at 150 °C the hydraulic conductivity is above the untreated at all measured densities, while the swelling pressure is consistently decreasing by dry thermal treatment at same temperature. Safety case is the tool applied by different waste management organizations, and HITEC results will be used in developing the safety case for higher temperatures, which should be both safe to apply and optimal e.g, for the cost of final disposal. For this purpose, HITEC will create a safety case guidance for higher repository temperatures. For High Level Waste it is important to assess the consequences of the heat pulse, which may affect the long-term performance of the barriers. Higher temperatures, than presently accepted 100 °C, while ensuring similar safety standards can have significant advantages with respect to disposing of higher enrichment/burn-up fuels, interim storage requirements, (re) packaging of the waste and reducing footprint of the disposal. HITEC offers much support in optimizing thermal dimensioning of HLW repository. HITEC aims to provide results that are applicable to a wide range of clay host rock and buffer material useful for different national programs. There is now only limited knowledge about the clay material behaviour at higher than 100 °C. However, the existing knowledge shows that mineralogical alteration will on acceptable level up to 150 °C. Therefore, the HITEC aims to increase scientific and technical knowledge mainly in mechanical behaviour of the clay materials. HITEC creates knowledge about higher temperatures, setting up limits of temperature and which kind of overall impacts higher temperatures causes to materials and systems. While HITEC produces important and interesting results about bentonite behaviour at elevated temperatures, it is however limited to mechanical behaviour only. Most bentonite processes are chemically driven by water, dissolved salt and mineral reactions, and therefore in the future including more chemistry in the mechanical studies should be included.

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