

Summary and evaluation by the End-User Review Board

Jarmo Lehtikoinen (Finnish Radiation and Nuclear
Safety Authority, STUK)

Jinsong Liu (Swedish Radiation Safety Authority,
SSM)



The research leading to these results has received funding from the European Atomic Energy Community's Seventh Framework Programme (FP7/2007-2011) under grant agreement 295487.



Introduction

- ✓ The emphasis in the evaluation of the presentations in the abstract collection has been on the merits and usefulness of the project outcomes mainly from the end-user (here, regulatory) point of view.
- ✓ However, it would be safe to say that the expertise of the consortium and the set of state-of-the-art experimental techniques used in the BELBaR project were truly impressive.



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Summary of the project achievements

- ✓ The project outcomes have the potential to pave way for new investigations where the most critical uncertainties are mitigated and managed, and bits and pieces of information put together systematically to expand the knowledge base.
- ✓ Such improved knowledge would also enable the construction of refined conceptual models to more credibly bound the potential risk posed by clay colloid formation and phenomena associated with it.



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Summary of the project achievements (cont'd)

- ✓ Thanks to the BELBaR project, the future performance assessments are in a better position to make more informed choices in a safety case to argue for the long-term performance of the bentonite-based barriers and the host rock and, ultimately, for the post-closure safety.
- ✓ The results and new insight gained from the project also enable both an implementor and a regulator to better identify, mitigate and manage the uncertainties anticipated to pose the greatest risk to the performance of a disposal system and to the post-closure safety.



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Evaluation of the meeting's presentations

The presentations are grouped into four topics:

- Characterisation
- Process study and mechanism understanding
- Colloid mobility and radionuclide sorption (ir)reversibility
- Modelling



Gratitude to the invited speakers

- We all really appreciate the speeches made by the invited speakers
- The presentations have brought the project to a wider perspective of the issues we are dealing with
- We will remember the video footage of clay avalanche and the cartoon picture of fertilising the lake.



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Characterisation (I)

- The End-User Review Board considers it very positive that a variety of analytical techniques, which had not previously been widely used in this area, have now been used to characterise the properties of bentonite and the colloids it forms.
- A large amount of information has been obtained and the information is valuable for performance assessment of a final repository
 - cation exchange capacity,
 - external and total surface areas
 - microstructure of the layered clay, etc.

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Characterisation (II)

- The aggregation and sedimentation behaviour of clay colloid particles have been much better understood, which can be of great importance for evaluation of the conservativeness of the different modelling approaches used in the performance assessment.
- The finding that the accessory minerals may lead to aggregation that otherwise does not occur is of great importance for the performance assessment and probably need to be further confirmed.



Characterisation (III)

- While characterising the rheological properties of clay suspensions the project reveals several interesting phenomena that may require further attention to be paid to when the results are incorporated in performance assessment.
 - to distinguish between gel and paste that is formed,
 - to consider the effect of edge-face interaction,
 - to unambiguously define a gel phase



Process study and mechanism understanding (I)

- The End-User Review Board has the opinion that the understanding of the mechanisms involved in the erosion process has been greatly deepened through this project.
- The erosion tests using artificial fracture and other setups have confirmed some of the previously gained understanding of the mechanisms
 - bentonite erosion is influenced by water flow rate,
 - hydration/water-saturation is related to relative humidity,
 - colloid stability depends on ionic strength of the solution and on the cation exchange properties of the bentonite,
 - particles of the accessory minerals are left behind during the erosion process and are also capable of mitigating erosion.

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Process study and mechanism understanding (II)

- It is of special interest that many new phenomena and processes related to the bentonite erosion have been discovered during the project.
 - the swelling of bentonite has different temperature dependences for swelling in monovalent and divalent counterion solutions,
 - the displacement along the axis of the sample is uneven during swelling, with largest displacement occurring at the end of the sample in direct contact with solution.



Process study and mechanism understanding (III)

- Regarding the colloid stability, several new findings possibly of great importance for performance assessment have been obtained.
 - the temperature dependence of the yielding of the gel has been shown to have an origin from edge-face interaction and enthalpy for such interaction has been obtained
 - the colloid stability depends not only on solution type and ionic strength, but also on pH. Could this be considered as evidence for edge-face interaction?



Process study and mechanism understanding (IV)

- Some relative new observations concerning the erosion behaviour of bentonite are:
- the erosion behaviour is more related to the smectite clay content than to the exchangeable counterion(s);
 - erosion in sloped fractures is substantially increased. (This phenomenon need to be considered in future performance assessments where Na-montmorillonite is assumed to form a conservative case, as it is known that Na-montmorillonite is more sensible to erosion. But Ca-montmorillonite has been observed to readily form stacks of platelets, making it more sensitive to sedimentation under gravitation.)



Process study and mechanism understanding (V)

- Intercalation of CO₂ into the interlayer of nano-space of smectite clay may lead to swelling. Can this phenomenon have significance for performance assessment?



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Colloid mobility and radionuclide sorption (ir)reversibility (I)

- The results gained still beg the question of full reversibility of radionuclides in actual repository conditions.
 - Key role of experimental time to attain full sorption reversibility.
- The much slower desorption rate for tetravalent actinides also begs the question of a conservative assumption regarding the reversibility of their sorption; would full irreversibility be such an assumption?



Colloid mobility and radionuclide sorption (ir)reversibility (II)

- Improved knowledge of the rates involved in the radionuclide desorption from bentonite colloids enables more credible assessments of the effect colloid-mediated radionuclide transport may have on the post-closure safety under varying flow conditions.
- Application of an average radionuclide distribution coefficient for all colloidal sizes was found acceptable in modelling.



Colloid mobility and radionuclide sorption (ir)reversibility (III)

- The lower affinity of radionuclides towards a dominantly divalent-cation form of bentonite than towards sodium form implies less colloid-mediated radionuclide transport.
- When bentonite colloids were found to have a non-negligible mobility, their potential to enhance radionuclide transport was evident. Clearly, this should have implications for whether or not colloid-mediated radionuclide transport should be considered in a safety case.



Colloid mobility and radionuclide sorption (ir)reversibility (IV)

- In hindsight, making normative assumptions, like “*Reversible, linear sorption of radionuclides onto colloids has been assumed*”, for a project is considered questionable as it could tacitly guide a practitioner to select parameters that support these assumptions (and to result in “self-fulfilling prophecies”) and may not serve to challenge the current understanding, although this likely has not taken place in the BELBaR project.



Colloid mobility and radionuclide sorption (ir)reversibility (V)

- An aspect that was not touched upon by WP3 concerns the role of biocolloids (e.g. bacteria) to mediate the radionuclide transport.
- While the End-User Review Board tend to agree with one of the partners in that the main uncertainties still remain in the quantification of colloids in actual repository conditions and in the mobility of colloids, WP3 certainly has succeeded in mitigating these uncertainties to be managed in a safety case while arguing for the post-closure safety.



Colloid mobility and radionuclide sorption (ir)reversibility (VI)

- It would also seem that the results from WP3 regarding radionuclide sorption (ir)reversibility and the role colloids may have in mediating radionuclide transport have implications for some of the issues in D1.2 that the project was planning to revisit.



Modelling (I)

- The End-User Review Board can give the comment that the modelling of bentonite erosion has made a large progress during the project, which has both increased the number of processes dealt with in the model, and enriched the tool-kit for performance assessment to select suitable models.



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Modelling (II)

- The classical “KTH-model” has been expanded and the numerical methods have been improved. The scaling approach has been developed based on the “KTH-model” by focusing on the system’s Péclet number.



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Modelling (III)

- An attempt has been made to model the ion-ion interaction, by using the weighted correlation approach in the framework of density function theory of statistic mechanics. The model may have significance in performance assessment for a better understanding and quantification of the erosion of Ca-montmorillonite.
- The novel density function approach to describe the selectivity of cation exchange process has paved the way for theoretical prediction of selectivity constants.



Modelling (IV)

- The electrophoretic mobility model has been introduced into the study of several processes related to erosion, such as surface conductivity effect.



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Thank you for your attention



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