Compaction, low gamma radiation and microbial interactions in bentonite: uncovering their combined impact on copper corrosion

Lidia Generelo-Casajús (1*), Mar Morales-Hidalgo (1), Marcos F. Martinez-Moreno (1), Cristina Povedano-Priego (1), Ana María Fernández (2), Úrsula Alonso (2), Fadwa Jroundi (1), Mohamed L. Merroun (1)

(1) Departamento de Microbiología. Universidad de Granada, 18003, Granada (España)
(2) Departamento de Fisión Nuclear. Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), 28040, Madrid (España)
* corresponding author: lidiagenerelo@ugr.es

Palabras Clave: Bentonita compactada, Baja radiación, Corrosión del cobre, Diversidad microbianas. **Key Words:** Compacted bentonite, Low radiation, Copper corrosion, Bacterial diversity.

INTRODUCTION

Deep Geological Repository (DGR) has been internationally accepted as a long-term storage option for high-level nuclear waste. These systems should operate until the radiation reaches natural levels and the engineered barriers (metal canister and buffer material) are not immune to the effects of deterioration. The most advanced DGR concept has selected copper (Cu) and bentonite as materials for the canister and buffer, respectively (Morales-Hidalgo et al*.,* 2024). On the other hand, microorganisms could compromise the safety of the disposal system, as they can induce corrosion of Cu canisters, producing various metabolic products including sulphides. Previous studies have focused on the presence of sulphate-reducing bacteria (SRB) in bentonite. These are of interest as they can use small molecules as electron donors and produce such sulphides which potentially can alter the chemical environment and accelerate the copper corrosion rate (Martinez-Moreno et al., 2023, Hall et al., 2021). In addition to microbial activity, abiotic factors, including bentonite compaction density and gamma radiation, can alter the chemical environment of the system and potentially affect the integrity of the DGR (Schmidt et al., 2021).

MATERIALS AND METHODS

Taking all this into account, the present study has investigated how physicochemical parameters, such as different compaction densities (1.4 g/cm^3 and 1.6 g/cm^3) and low gamma radiation at a total cumulative dose of 1 kGy, could affect bentonite stability, the native bacterial communities in bentonite and impact on Cu corrosion. To achieve this, Spanish bentonite was compacted at two different densities, in triplicate, with each block containing a Cu disc at its core. All bentonite blocks were incubated for six months under anoxic conditions and at 30 ºC.

RESULTS AND DISCUSSION

The preliminary results revealed no significant changes in the mineralogical stability of bentonite after six months of anoxic incubation under the specified conditions. In addition, it was confirmed that both compaction densities remained constant throughout the incubation period. At the same time, changes in the microbial community were analysed by Next Generation Sequencing of the V3-V4 region of the 16S rRNA gene. Natural bentonite revealed an initial community including representatives from the genera *Pseudomonas*, *Saccharopolyspora*, *Acinetobacter*, and *Streptomyces*, which can thrive in extreme conditions and have the ability to sporulate. Due to the presence of pores in compacted bentonite where oxygen molecules can be retained, the survival of aerobic bacteria capable of enduring the studied parameters was observed in all samples. Some bacteria of interest were isolated and identified molecularly. Due to their impact on copper corrosion, the viability of SRB was also evaluated using a specific culture medium for this bacterial group known as Postgate (DSMZ_Medium63, dsmz.es). All the treatments revealed positive results for the growth of this bacterial group. Additionally, the corrosion rate of Cu discs was calculated, revealing a greater thickness loss in the 1.4 g/cm^3 Cu disc. This suggests that compaction density may influence Cu corrosion. Furthermore, VP-FESEM Cu surface characterization, combined with EDX microanalysis, showed detached layers and fully covered surfaces with different corrosion products. Copper oxides of different morphologies were predominant and were also found associated with bacteria and bentonite.

CONCLUSIONS

Based on the results of the six-month incubation, it was found that native bacteria from bentonite were able to withstand low doses of radiation, both aerobic and sulphate-reducing bacteria. In the 1.4 g/cm3 compacted block, the Cu disc suffered a higher corrosion rate, and a possible bacterial biofilm was observed within the bentonite. Furthermore, precipitates of copper oxides were found on the surface of both discs. Overall, the findings of this study enhance our understanding of how key combined factors may influence the biogeochemical processes at the interfaces between bentonite and copper canisters.

REFERENCES

Hall, D.S., Behazin, M., Jeffrey Binns, W., Keech, P.G. (2021): An evaluation of corrosion processes affecting copper-coated nuclear waste containers in a deep geological repository. Progress in Materials Science **118**, 100766. DOI: 10.1016/j.pmatsci.2020.100766.

Schmidt F., Hosemann, Raluca, O., Scarlat, Schreiber D.K.., Scully J. R.., Uberuaga B. (2021): Effects of radiation-induced defects on corrosion. Annual Review of Materials Research., **51**, 293-328. DOI: 10.1146/annurev-matsci-080819-123403.

Morales-Hidalgo M., Povedano-Priego C., Martinez-Moreno MF., Ruiz-Fresneda MA., Lopez-Fernandez M., Jroundi F., Merroun ML. (2024): Insights into the Impact of Physicochemical and Microbiological Parameters on the Safety Performance of Deep Geological Repositories. Microorganisms. **12**(5),1025. DOI: 10.3390/microorganisms12051025.

Martinez-Moreno MF., Povedano-Priego C., Morales-Hidalgo M., Mumford AD., Ojeda JJ., Jroundi F., Merroun ML. (2023) Impact of compacted bentonite microbial community on the clay mineralogy and copper canister corrosion: a multidisciplinary approach in view of a safe Deep Geological Repository of nuclear wastes. Journal of Hazardous Materials. **458**, 131940. DOI: 10.1016/j.jhazmat.2023.131940.