INTERPLAY OF PHYSICOCHEMICAL AND MICROBIAL PROCESSES UNDER REPOSITORY-RELEVANT CONDITIONS: UNCOVERING THEIR IMPACT ON THE CORROSION OF CANDIDATE MATERIALS FOR METAL CANISTERS

Presenting: **Lidia Generelo Casajús,** PhD student

Mohamed L. Merroun, Department of Microbiology. Ursula Alonso, Department of Nuclear Fission

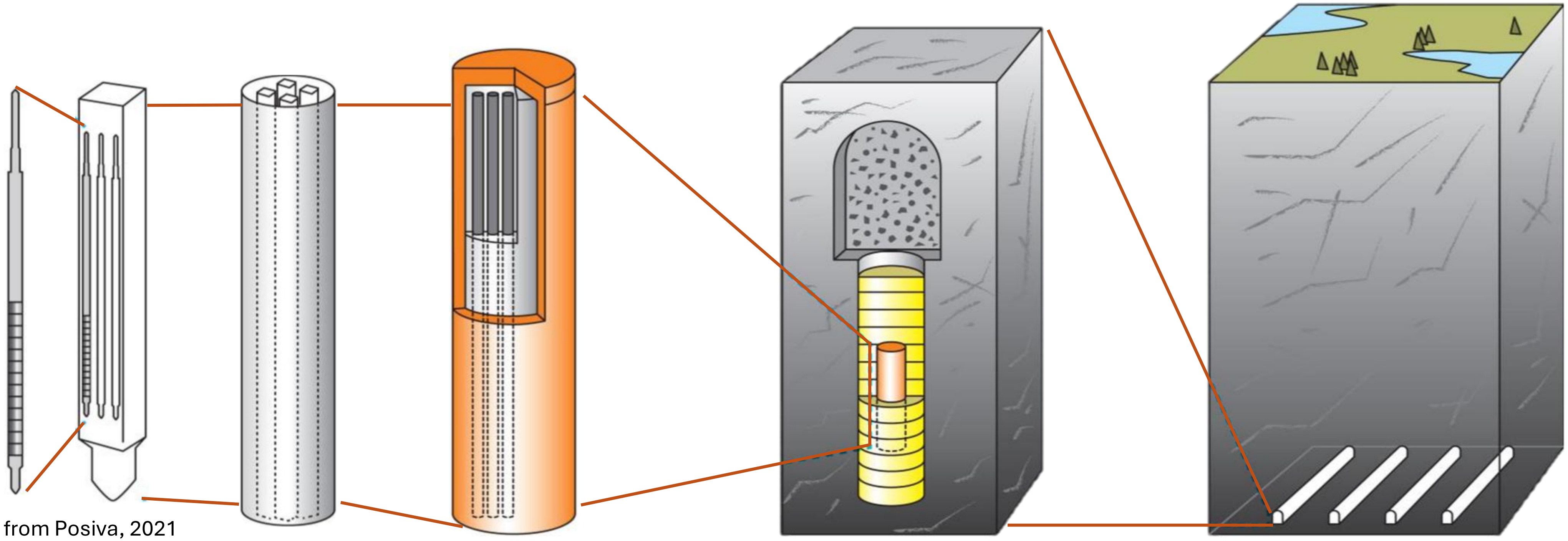
Co-funded by the European Union under Grant Agreement n° 101166718

1. Deep Geological Repository (DGR)

Disposal of high-level waste (HLW)

Operational until **radiotoxicity** reaches **natural levels** (≈ 100,000 years)

Multi-barrier system for the safe encapsulation of radioactive waste



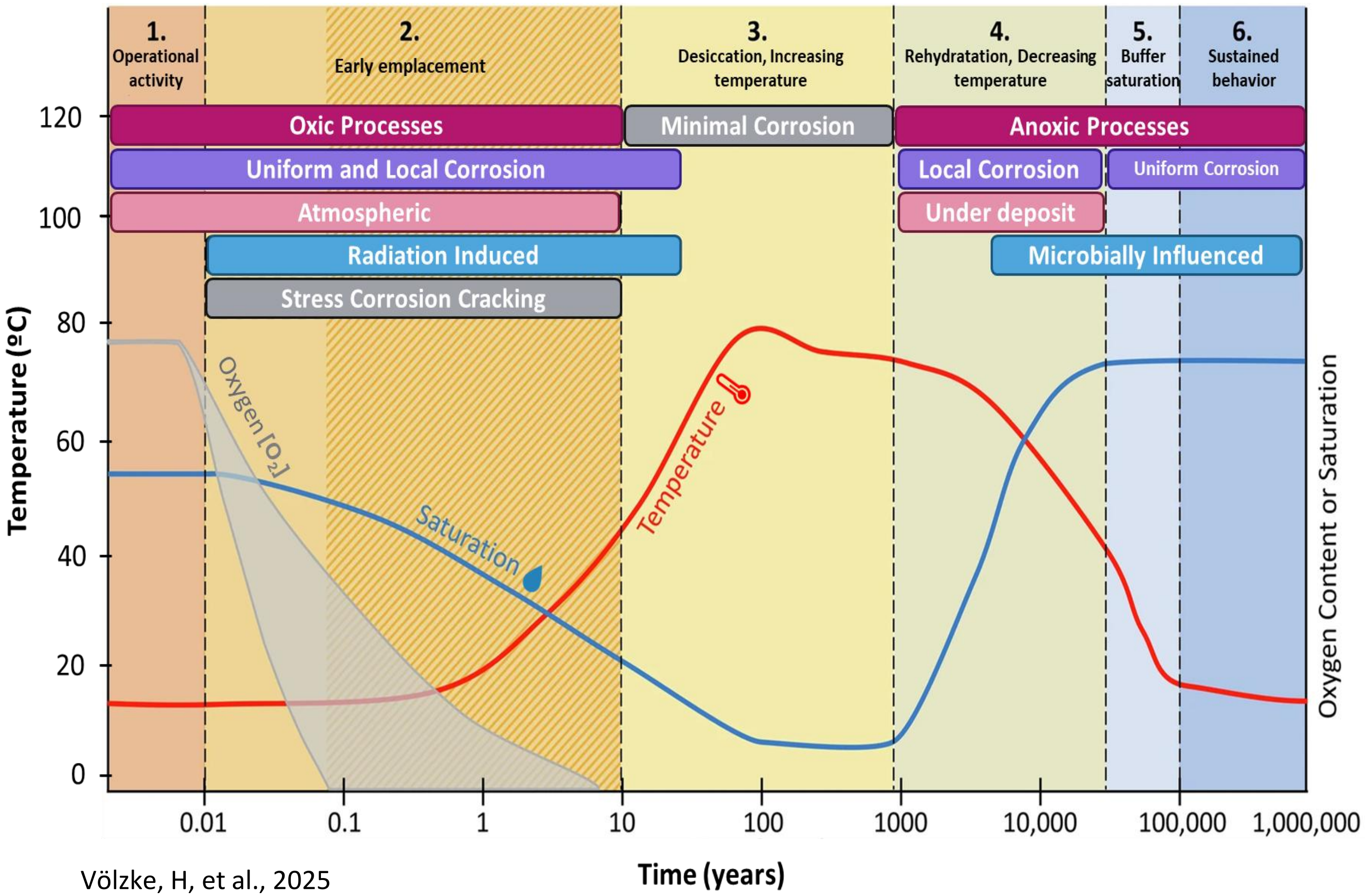
Modified from Posiva, 2021

High-level waste	Engineered barriers		Natural barrier
	Enclosure of HLW in **metal canisters** (**copper**)	Encapsulated in a **sealing material** (**compacted bentonite**)	Emplaced in **host rock** (**at depth of 400 – 500 m**)

SKB and POSIVA concept

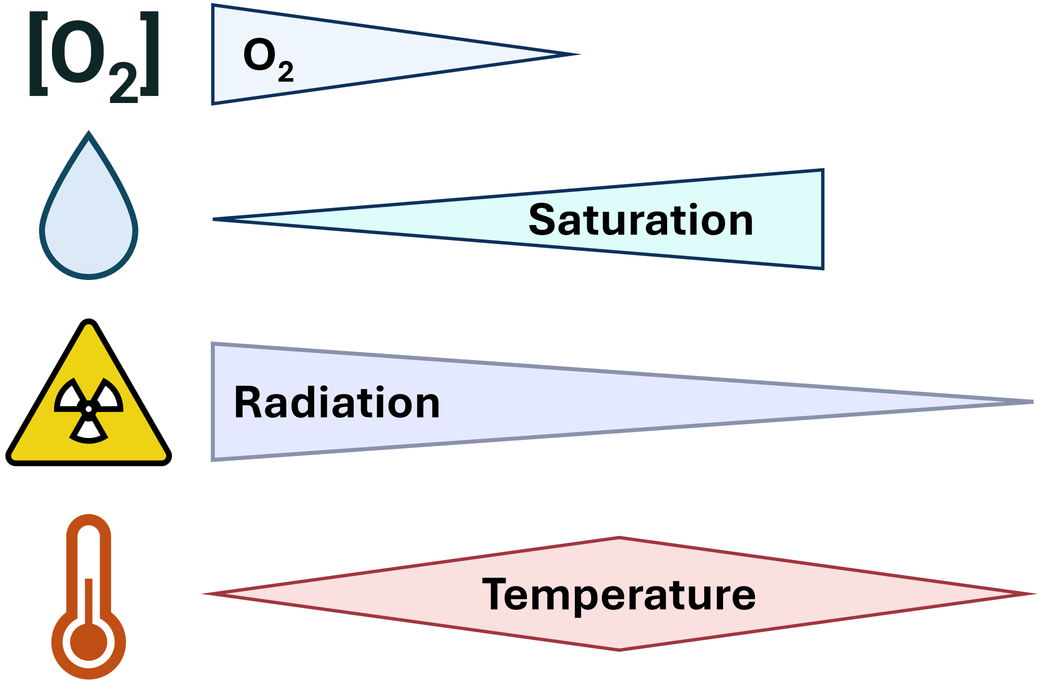
1. Deep Geological Repository (DGR)

Evolutionary conditions



Völzke, H, et al., 2025

Abiotic factors



Biotic factors

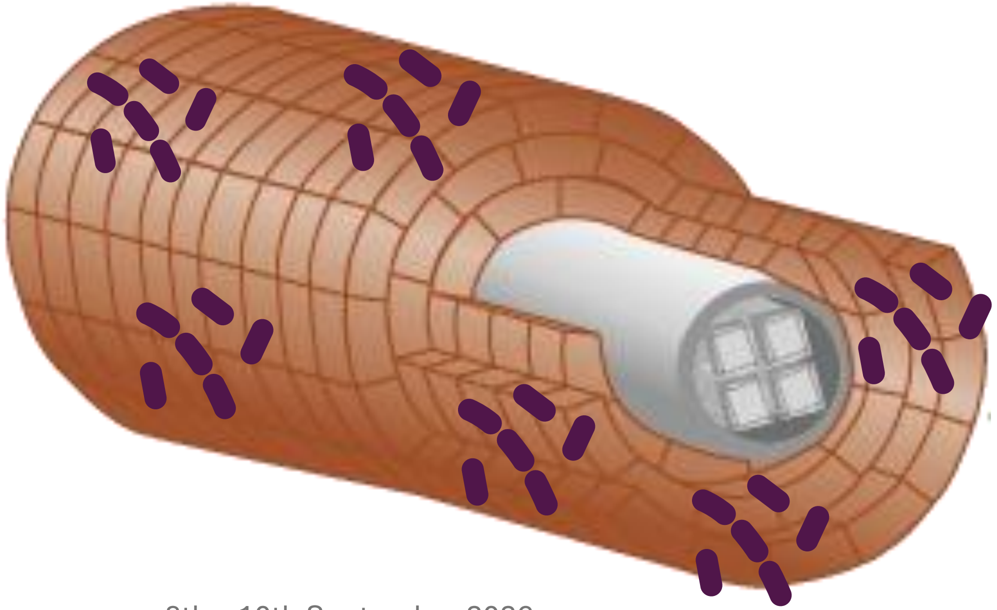
Microbial induced corrosion (MIC)

1. Deep Geological Repository (DGR)

Presence of microorganisms

Repositories are **not sterile environments**, and **indigenous microbial communities** are naturally present

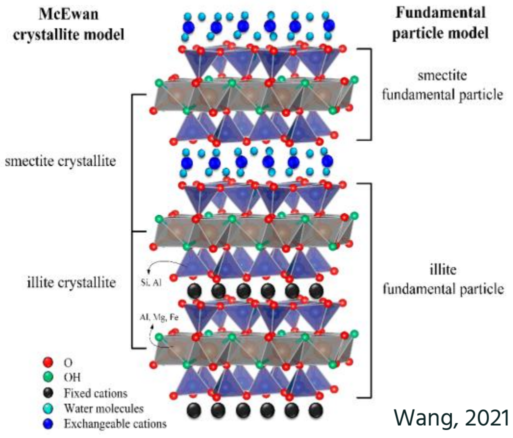
Microbial metabolic activity may influence key **biogeochemical processes**



Biotic factors

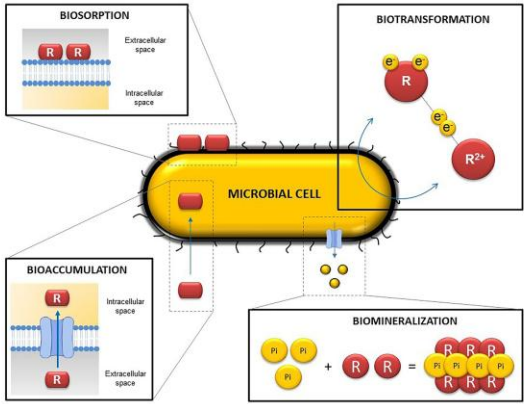
Bentonite mineralogy **transformation**

Illitization of smectite



Wang, 2021

Mobilization of **radionuclides**

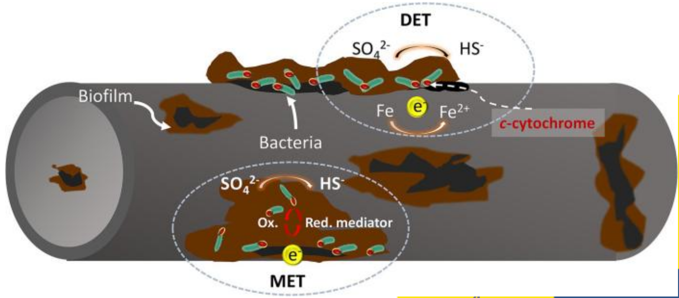


Ruiz-Fresneda et al., 2023

Corrosion of metal **canisters**

Microbial influenced corrosion (MIC)

Sulfate-reducing bacteria (SRB)



2. Building on Previous Results

Previous results from EURAD – WP15 ConCorD

- **High γ-radiation** (14 kGy and 28 kGy) **negatively affected** the **viability** of **aerobic heterotrophic** microorganisms and **SRB**
- **Gamma radiation indirectly delayed** the **biotic corrosion** of copper

Non-irradiated

Double - irradiated (28 kGy)

New research for EURAD2 – WP9 InCoManD

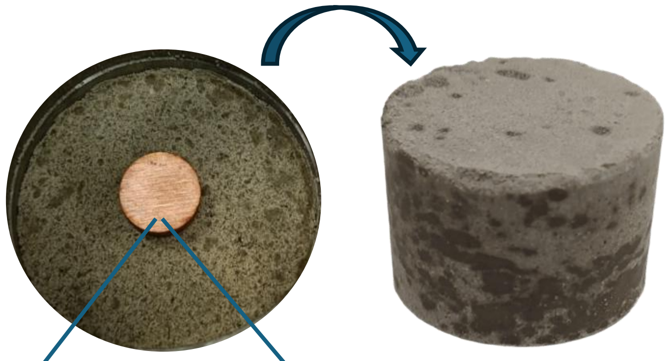
- Determine the **radiation threshold** for **microbial presence** and **activity**
- Evaluate the impact of **bentonite compaction** and **radiation** on **shifts** in bentonite autochthonous **microbial communities**
- Study the interplay of **bentonite compaction** density and **radiation** on **copper corrosion**

InCoManD

eurad 2

3. Recreation of representative repository conditions

Compacted and **γ-irradiated** FEBEX bentonite

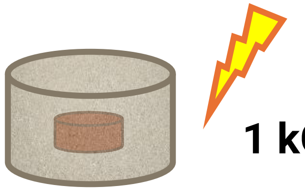


Copper disks
(10 mm Ø , 4 mm h)

Representative repository conditions
(**radiation**, **humidity** and **anoxic** conditions)

1: LOW RADIATION EXPOSURE (LR) – 1 kGy (66 Gy/h)

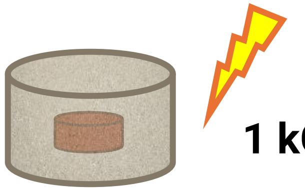
1.4 g/cm³
compacted
FEBEX bentonite



1 kGy

LR_1.4

1.6 g/cm³

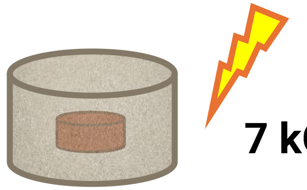


1 kGy

LR_1.6

2: MEDIUM RADIATION EXPOSURE (MR) – 7 kGy (48 Gy/h)

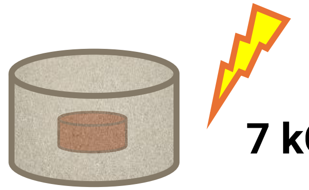
1.4 g/cm³
compacted
FEBEX bentonite



7 kGy

MR_1.4

1.6 g/cm³



7 kGy

MR_1.6

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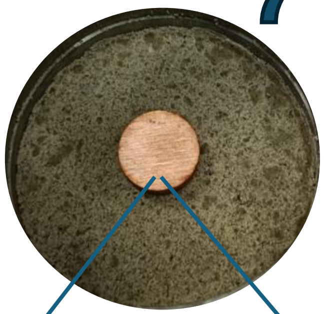
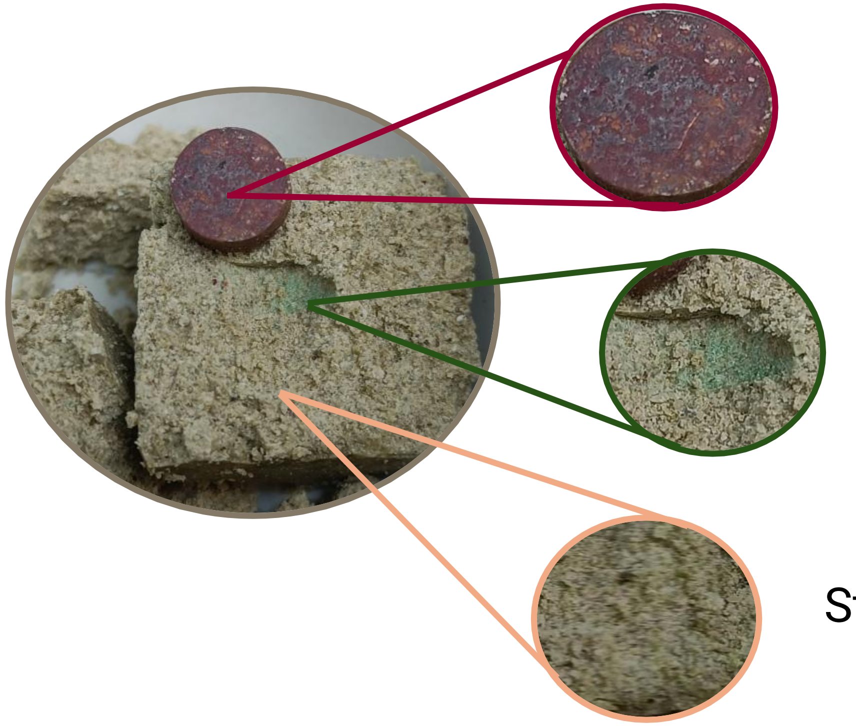
Compacted and **γ-irradiated** FEBEX bentonite



Copper disks
(10 mm Ø , 4 mm h)

Representative repository conditions
(**radiation**, **humidity** and **anoxic** conditions)

Analysis using multidisciplinary methodologies



Characterization of copper **corrosion products**

Assessment of **mineralogical changes**

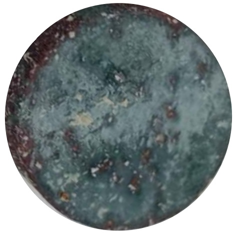
Study of the **native microbial communities** in bentonite

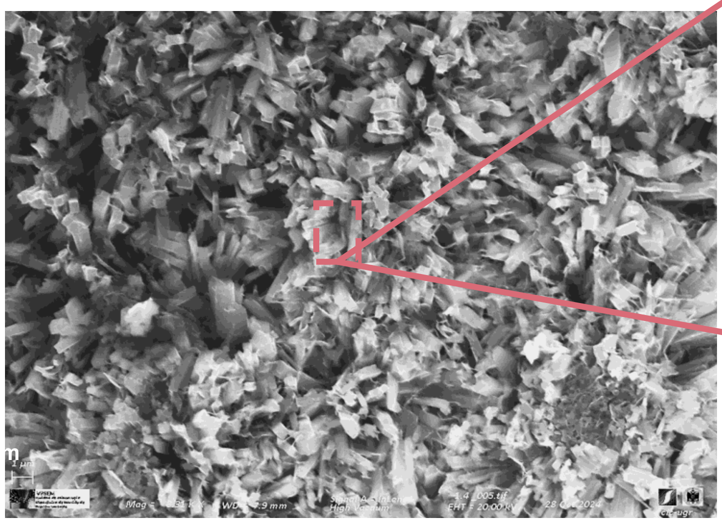
4. Analysis of corrosion products

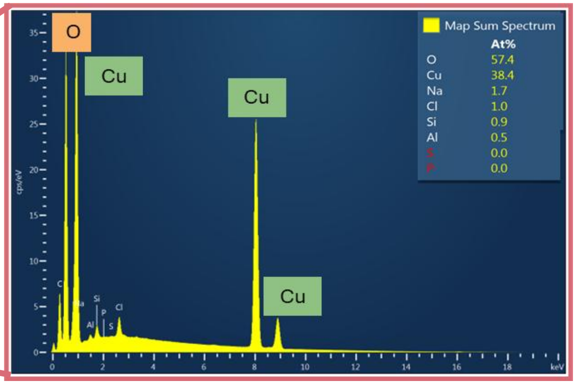
1: LOW RADIATION EXPOSURE (LR) – 1 kGy (66 Gy/h)

1 kGy

1.4 g/cm^3

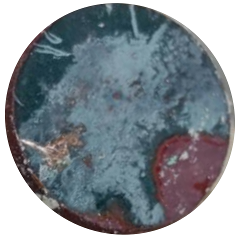


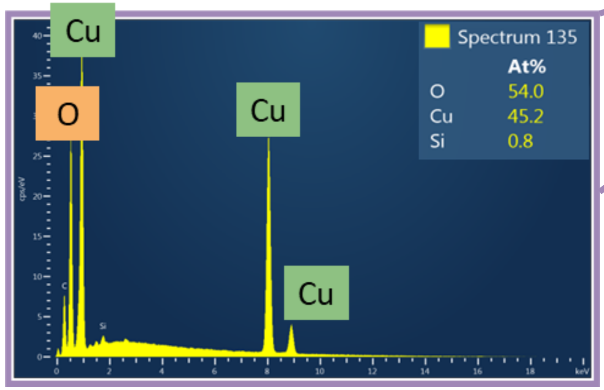


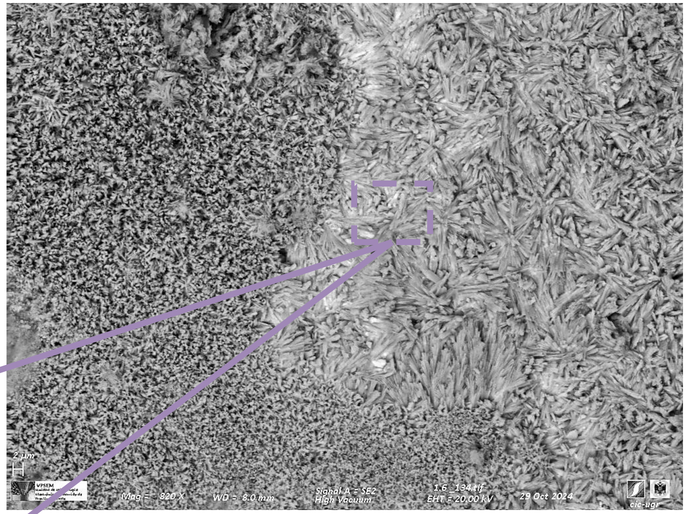


1 kGy

1.6 g/cm^3







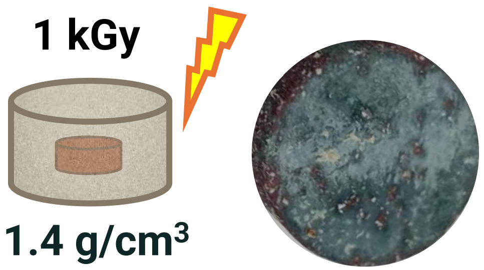
The main corrosion products in both treatments were **needle-shaped copper oxide precipitates**

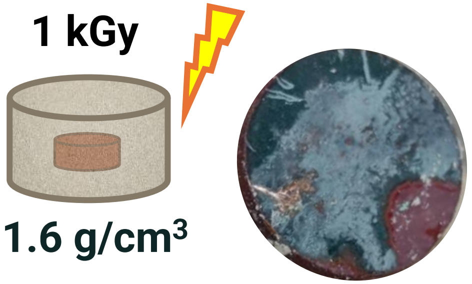
Needle-shaped copper oxide precipitates

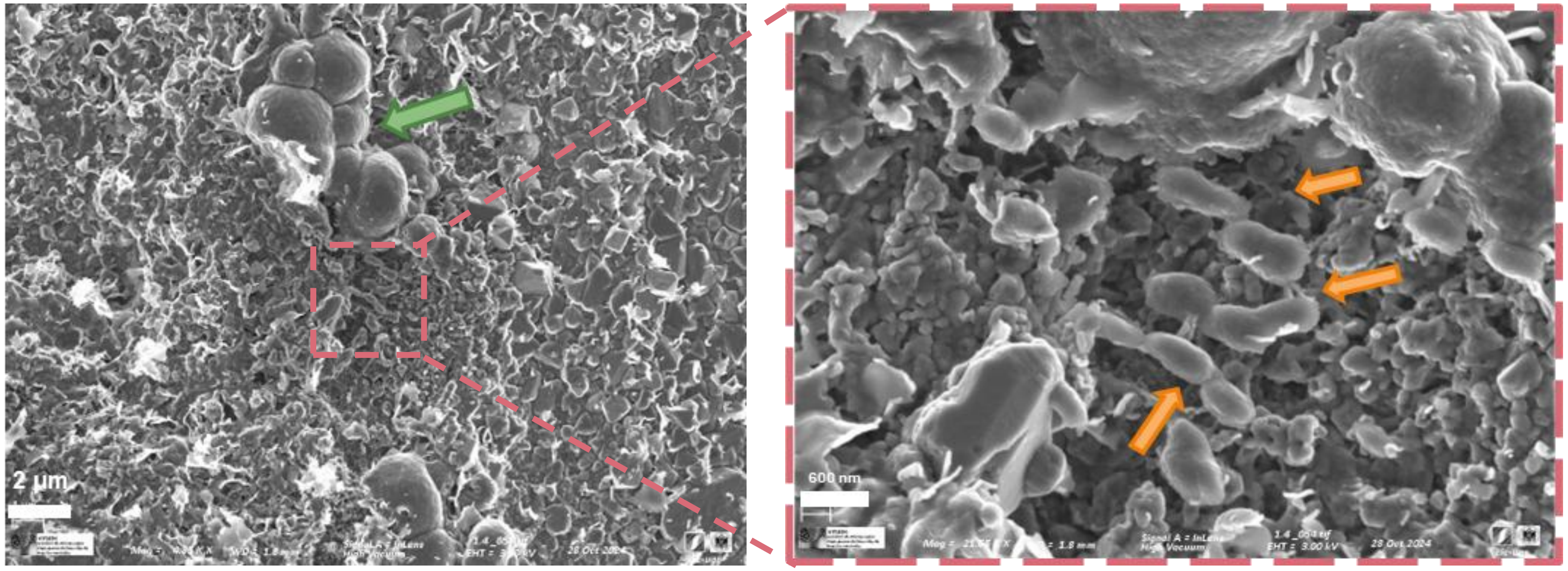
2

4. Analysis of corrosion products

1: LOW RADIATION EXPOSURE (LR) – 1 kGy (66 Gy/h)







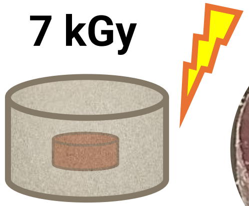
No biofilm within the bentonite was observed at high compaction density

Carbon-containing accumulations between bentonite, which appear to be a **microbiological biofilm**

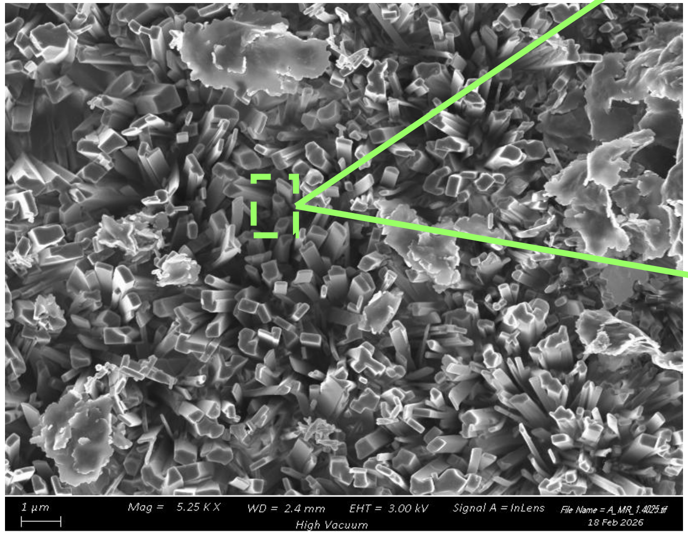
4. Analysis of corrosion products

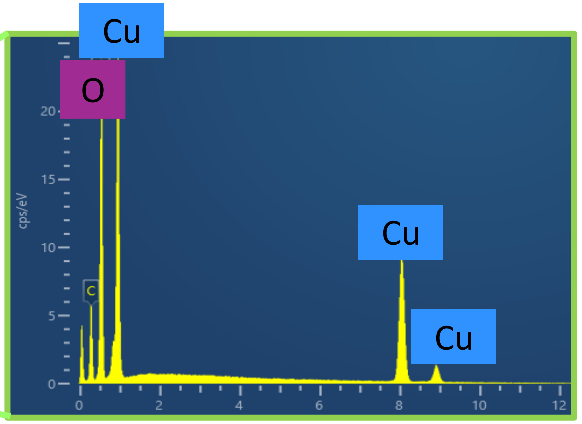
2: MEDIUM RADIATION EXPOSURE (MR) – 7 kGy (48 Gy/h)

7 kGy



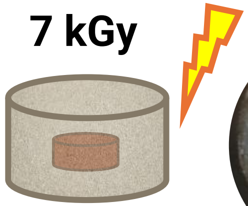
1.4 g/cm³



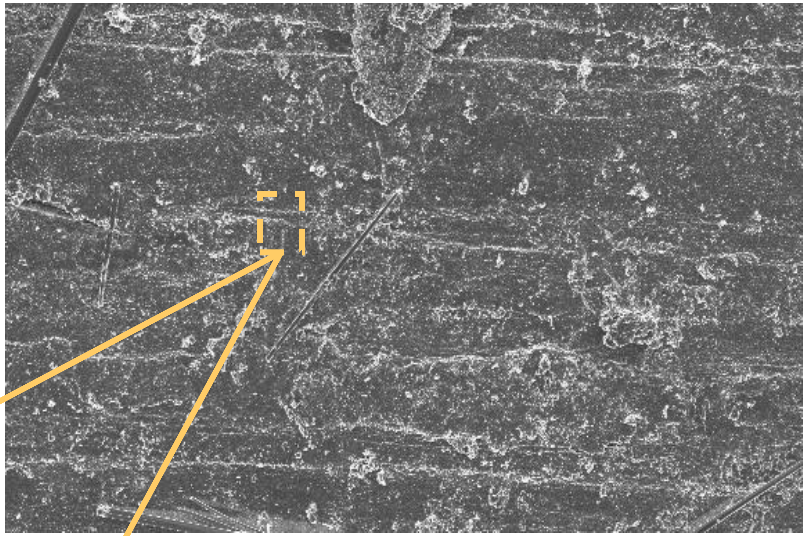


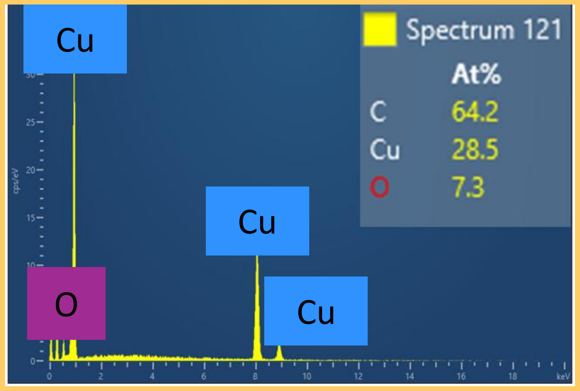
Needle-shaped precipitates of possible **copper oxides**

7 kGy



1.6 g/cm³



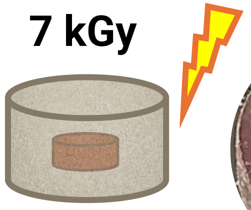


Possible **copper oxide** precipitates

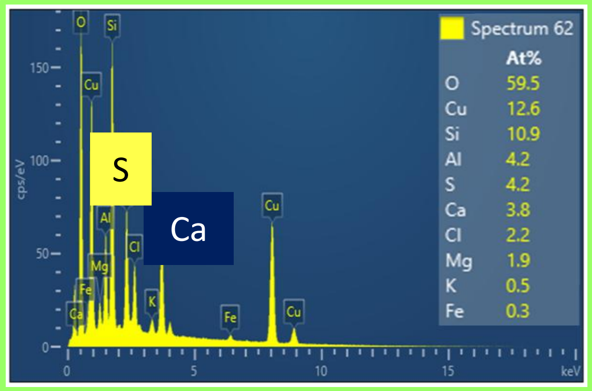
4. Analysis of corrosion products

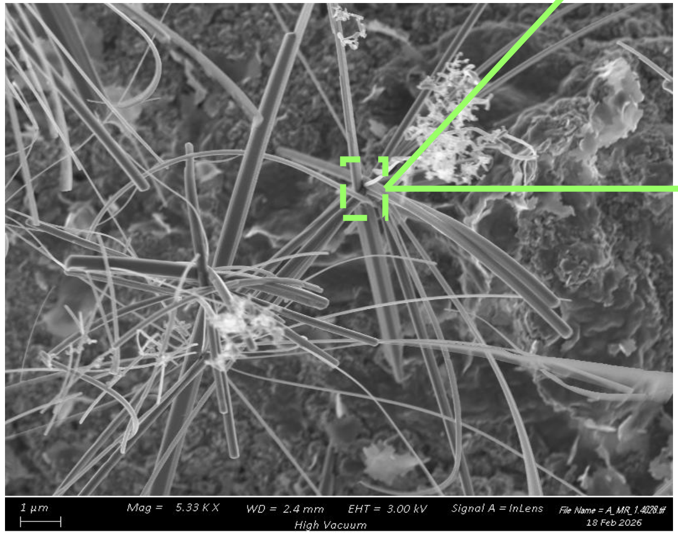
2: MEDIUM RADIATION EXPOSURE (MR) – 7 kGy (48 Gy/h)

7 kGy



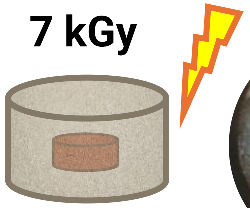
1.4 g/cm³





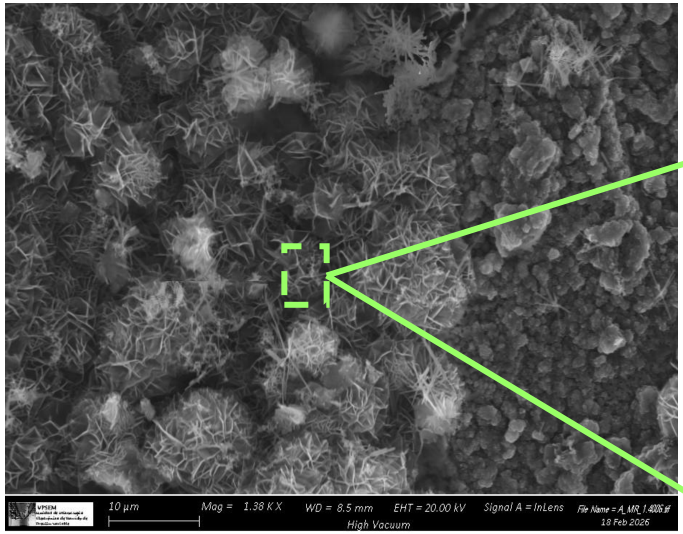
Acicular crystals of **sulfur** and **calcium (gypsum)**

7 kGy

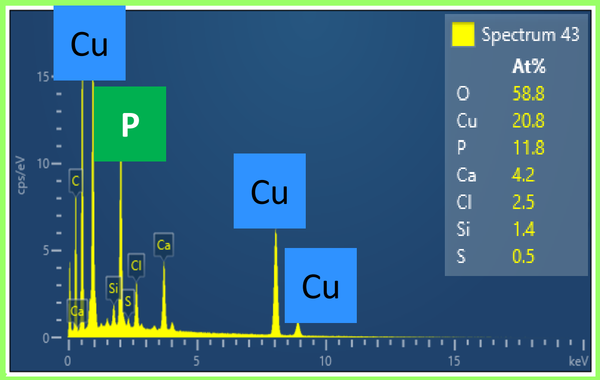


1.6 g/cm³

Clean disk surface with **minimal damage**



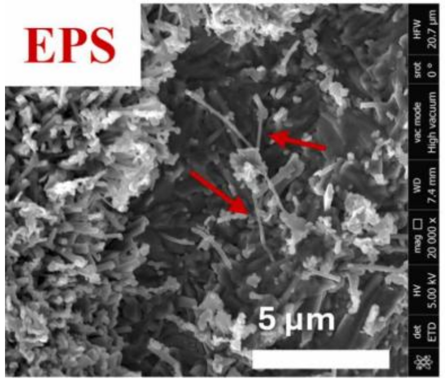
Rosette-like microstructures



5. Survival of sulfate-reducing bacteria

No sulfides were detected by **microscopy**

Is this evidence of the **absence of sulfate-reducing bacteria (SRB) activity**?



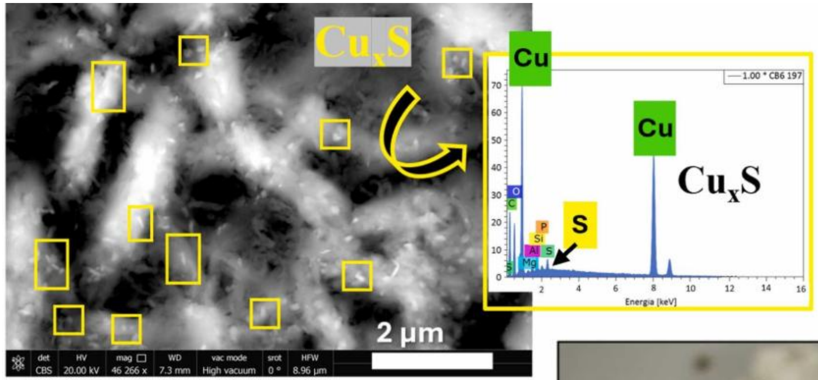
Morales-Hidalgo et al. 2026

Sulfate-reducing bacteria (SRB)

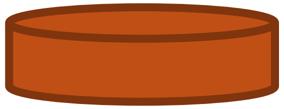
e^- donors → CO_2

Sulfate → **Sulfide**

Cu → **Cu_xS**



Morales-Hidalgo et al. 2026

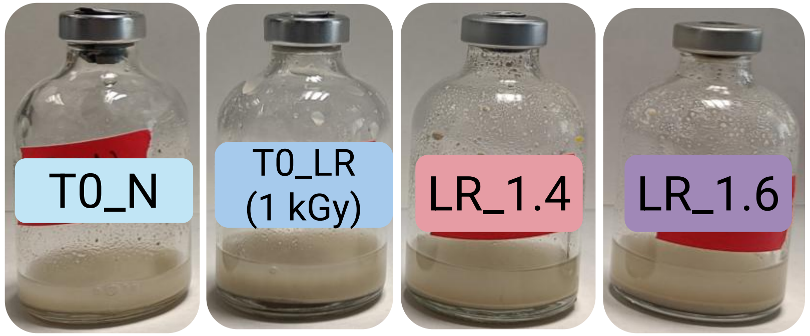


Do **SRB** remain **viable** after exposure to **different doses of gamma radiation**?

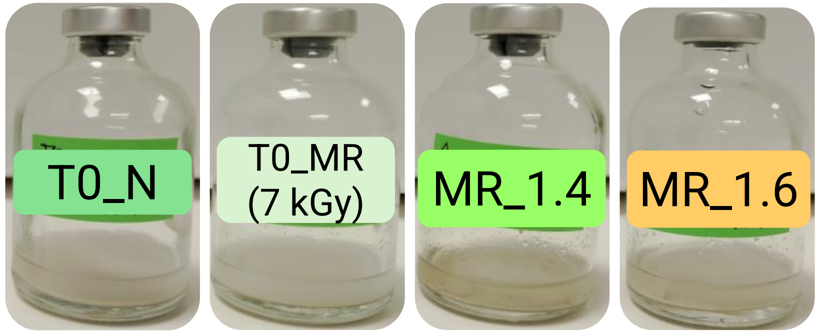
Is the observed **corrosion** primarily **abiotic** or **biotic** in nature?

5. Survival of sulfate-reducing bacteria

LOW RADIATION EXPOSURE (LR) – 1 kGy (66 Gy/h)



MEDIUM RADIATION EXPOSURE (MR) – 7 kGy (48 Gy/h)



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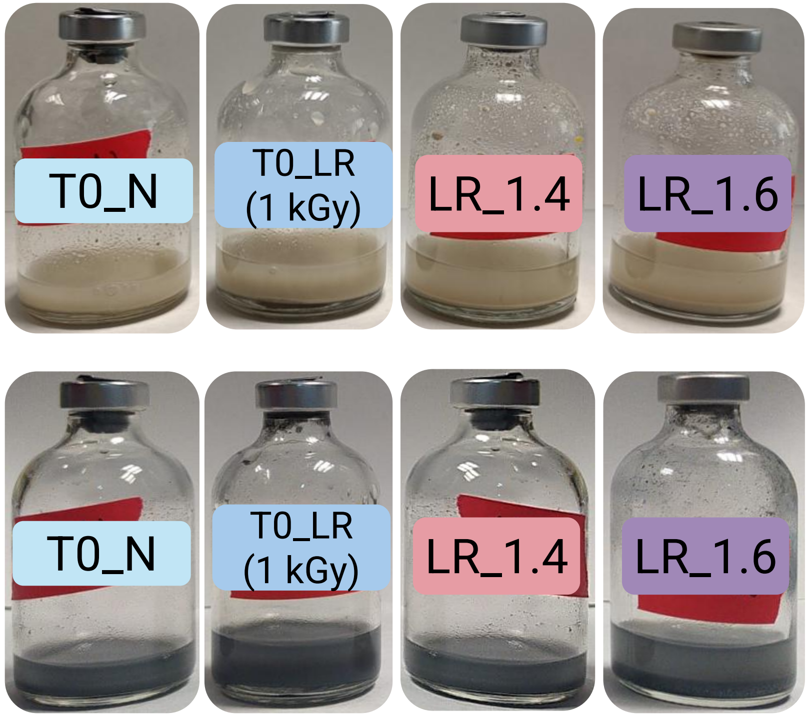
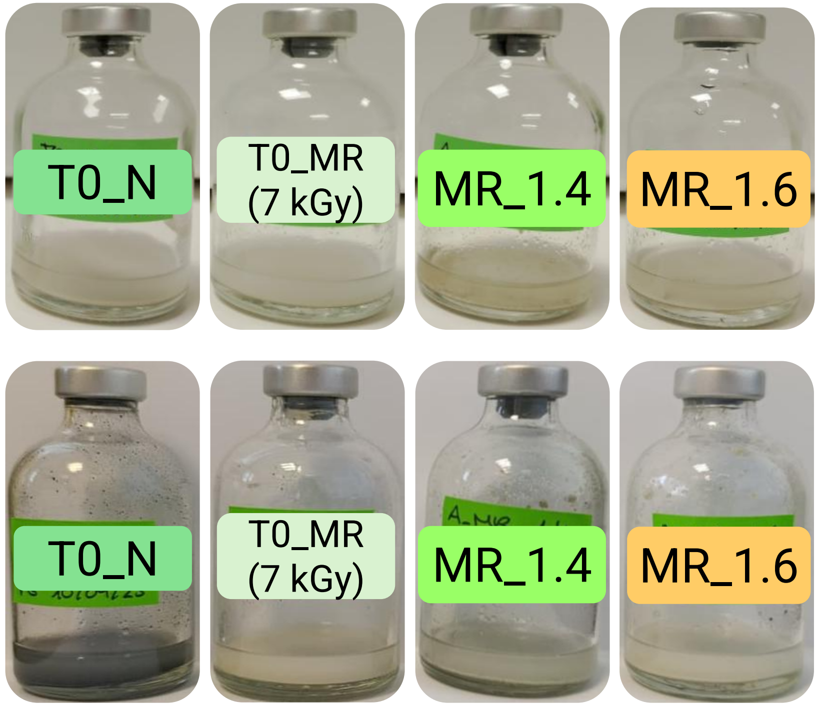


All media show **growth of SRB** after **40 days**

Under **optimal conditions SRB restore** their **metabolic activity**, as indicated by the black color

MEDIUM RADIATION EXPOSURE (MR) – 7 kGy (48 Gy/h)



Only natural bentonite show **growth of SRB** after **40 days**

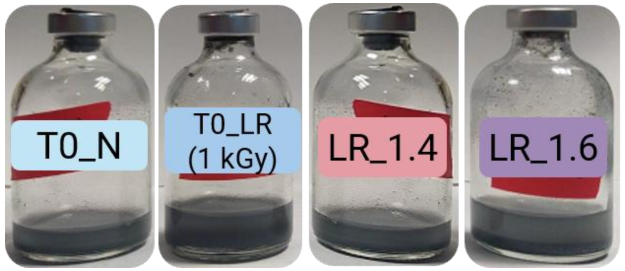
No metabolic activity was recovered after restoring optimal conditions

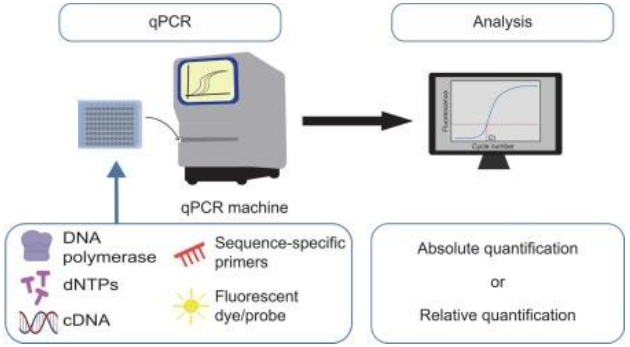
Irradiation at **7 kGy** leads to a **loss of SRB viability**

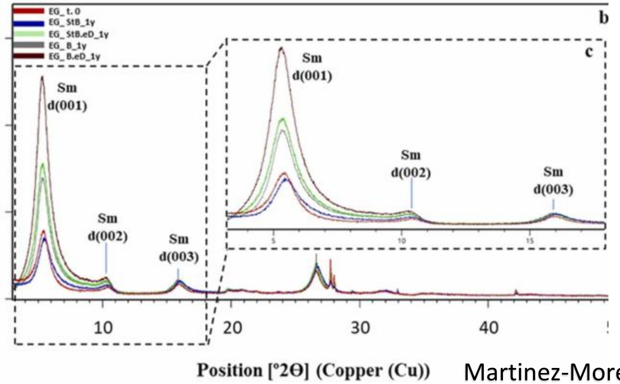
7. Looking ahead

Study of the **native microbial communities** in bentonite

Assessment of **mineralogical changes**







Martinez-Moreno et al. 2023

Evaluate the effects of **radiation** and **microbial activity** on **bentonite properties**

Identify **radiation-resistant microorganisms**

NGS Illumina 16S rRNA gene sequencing

Investigate the effects of **compaction** and **radiation** on **microbial community dynamics**

Identify potential **new mineral phases** formed under studied conditions

Ciemat

Acknowledgements

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Ciemat

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Dra. Ana María Fernández

Founding

eurad 2 European Partnership on Radioactive Waste Management

InCoMAnD

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AGENCIA ESTATAL DE INVESTIGACIÓN

PID2022-138402NB-C21

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Thank you for your attention

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Lidia Generelo Casajús

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