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How bentonite microbial communities and copper canisters respond to nuclear waste repository conditions: effects of gamma radiation and high compaction

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The deep geological repository (DGR) concept is based on a multi-barrier system designed to safely manage high-level radioactive waste (HLW) while ensuring its long-term containment and integrity. The first protective barrier consists of corrosion-resistant metal canisters, such as copper, which encapsulate radioactive waste. The second engineered barrier acts as a backfill and sealing material, playing a crucial role in containing, absorbing, and confining any potential waste leakage while also slowing groundwater infiltration. This barrier is composed of highly compacted bentonite blocks, ensuring the effective integration of clay within the system. Once sealed, the environmental conditions within the DGR will not remain static but will evolve over time. Key variables expected to fluctuate include oxygen levels, radiation doses, temperature, and water availability.

This study investigates the combined impact of high compaction density (1.6 g/cm^3) and gamma radiation exposure (14 kGy or 28 kGy) under conditions of pore water saturation, sulfate-reducing bacteria (SRB) presence, and an anoxic atmosphere on FEBEX bentonite blocks. To assess corrosion effects, small pure-copper disks were included in the core of each block. The bentonite and copper disks were analyzed using a combination of microbiological methods (both molecular and culture-dependent), along with microscopic and spectroscopic techniques. After one year of incubation in anoxic conditions, bacterial diversity was predominantly composed of spore-forming genera capable of surviving extreme environments such as desiccation conditions. Among these, *Saccharopolyspora* was relatively abundant. Overall, gamma radiation at the study doses negatively affected the viability of native bentonite communities, as well as the SRB consortium. However, one of the key findings of the study was that an incubation period before radiation exposure enhanced microbial resistance to this effect. Research on copper corrosion showed that copper oxides, particularly CuO, were the predominant corrosion products across all samples. Moreover, gamma radiation hindered biotic corrosion by disrupting the microbial community. The SRB were found to be involved in the formation of biogenic copper sulfides, which were exclusively detected within the bentonite.

This study provides fresh insights into the combined impact of gamma radiation and other critical DGR conditions on bentonite microbiology and copper corrosion.