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Impact of microbial metabolism on P-cement under GDF relevant conditions

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A Geological Disposal Facility (GDF) is a multi-barrier system designed for the safe and permanent disposal of radioactive waste, which is produced as a byproduct of nuclear power generation, military applications, industry, medical fields, and research facilities. Cement will be used extensively in this multi-barrier system, playing a crucial role in ensuring its long-term integrity. However, the production of Ordinary Portland Cement (OPC) contributes significantly to carbon emissions. As the world moves toward a carbon-neutral future, phosphate-based cement has emerged as a promising alternative to OPC, offering comparable mechanical properties. Due to other properties such as less alkaline pH, less aggressive pore-solution and high environmental resistance, phosphate-based cement is gaining attention for potential use in radioactive waste disposal. This study investigates the interactions between microbes and a magnesium potassium phosphate cement (MKPC). Over time, microbial growth may occur in a GDF, which may impact on cement integrity. The composition of phosphate-based cement can provide essential nutrients including phosphate for microbial growth. This may lead to alteration of the cement properties. To study this, experimental systems were established with MKPC pellets and a microbial inoculum enriched from alkaline Harpur hill sediment: (1) Control (groundwater + cement + inoculum), (2) No-added phosphate (groundwater + cement + lactate + nitrate + inoculum), and (3) Added phosphate (groundwater + cement + lactate + nitrate + phosphate + inoculum). Additionally, (4) no-nitrate (electron acceptor) controls were included. The experiments were conducted under anaerobic conditions at 30°C for three months. Geochemical analysis confirmed a decrease in pH (consistent with microbial growth) in both the no-added and added phosphate systems after two months, accompanied with phosphate release to solution. Scanning Electron Microscopy (SEM) revealed the formation of new mineral phases and increased surface pitting in both these systems. Laser confocal microscopy further confirmed changes in surface texture and an increase in pit diameter. However, no significant changes were observed in the lower microbial activity control and no-nitrate systems. These findings suggest that microbial interactions with MKPC may accelerate cement dissolution and degradation, which has important implications for the use of MKPC cement in radioactive waste disposal.