Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.36986

Effect of Storage Period during Aquifer Storage and Recovery (ASR) on the Microbe-mediated Natural Attenuation of Dissolved Organic Carbon: Laboratory Column Experiments

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Aquifer Storage and Recovery (ASR) is known to improve the recharged water quality through various biogeochemical reactions. Biodegradation is the primary mechanism responsible for dissolved organic carbon (DOC) removal during ASR, and an adequate storage period is essential for efficient microbial processing and water quality stabilization. This study investigated the influence of storage period during ASR on the efficiency of DOC attenuation by conducting the controlled column experiments with soils containing iron oxide minerals. Recharging water was subjected to different storage durations (3-, 10-, 30-, and 60-day), and DOC removal efficiency with potential redox-sensitive mineral transformation was investigated over repeated recharging events. Although approximately 85% DOC removal was achieved under all storage conditions, the required time for the maximum removal efficiency differed significantly. At the 3-day storage condition, the short interval between recharging events caused frequent alternation between aerobic and anaerobic state in the pore water condition, due to continuous inflow of oxygenated recharging water. These repeated redox shifts likely delayed the stabilization and activity of iron-reducing bacteria (IRB), thereby slowing the enhancement of biodegradation. In contrast, longer storage periods (10-, 30-, and 60-day conditions) provided sufficient time for the early establishment of stable anaerobic environments. This facilitated active biodegradation mediated by IRB and enabled earlier attainment of peak DOC removal efficiency. Microbial community analysis supported these observations, showing greater prevalence of anaerobic taxa, including IRB, under the 30- and 60-day conditions compared with the shorter storage intervals. Furthermore, differences in storage duration were associated with variations in the crystallization and transformation of redox-sensitive iron minerals. Overall, the results demonstrate that storage period could critically control redox stabilization, microbial community development, and DOC attenuation kinetics in the aquifer during ASR. Optimizing storage duration is therefore essential for enhancing biogeochemical performance and ensuring long-term water quality improvement in ASR systems.