Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.36332

Transport and transformation of redox-sensitive species in a pit-lake bank filtration system in Quebec, Canada

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Sustainable groundwater management is critical as water scarcity and water quality degradation intensify. Managed Aquifer Recharge (MAR) is a widely recognized approach for improving groundwater recharge and stabilizing aquifer levels. Among MAR techniques, induced bank filtration (IBF) offers additional advantages by promoting natural attenuation of organic and microbial contaminants, reducing treatment requirements. Previous studies have shown that the infiltration of carbon and oxygen-rich surface water can alter subsurface redox conditions, thereby mobilizing geogenic species like Fe and Mn, leading to undesirable levels in drinking water. Most IBF studies focus on systems adjacent to rivers. In contrast, IBF configurations are diverse and include systems adjacent to pit lakes, which often develop thermal stratification influencing hydrogeochemical and redox conditions. At an IBF site in Quebec, Canada, operating since 2013, increasing Fe and Mn concentrations have been observed. Given the complex hydrogeological configuration—eight pumping wells located between two pit lakes (A and B), both contributing to induced infiltration—a thorough investigation was undertaken to identify the processes controlling Fe and Mn concentrations in the bank filtrate. One production well (P5), among those exhibiting the most degraded water quality, was subjected to continuous pumping for 80 days. Weekly samples were collected from P5 and from an adjacent observation well (Z15), positioned between Lake B and the pump P5. Redox-sensitive chemical species and other physico-chemical parameters were monitored. Three sampling campaigns were conducted on Lake B in 2025, complemented by historical data from Lake A. Results indicate a progressive shift from reducing to mildly oxidizing conditions near P5 over the study period, as shown by decreasing H_2S concentrations and increasing NO_3 concentrations. Total Fe and Mn concentrations in Z15 closely match those to the hypolimnion of Lake B, whereas P5 values fall between those of lakes A and B. These observations suggest that mixing and advective transport dominate Fe and Mn dynamics. The behavior of other redox species like SO_4, NO_3 and H_2S, indicates that additional redox reactions also occur. Identifying the controls on the transport and transformation of redox-sensitive species provides critical insight for anticipating water quality evolution in pit-lake bank filtration systems.