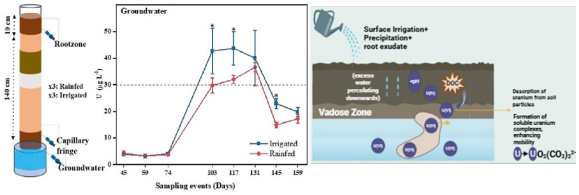
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Surface irrigation induced uranium mobility in the vadose zone – groundwater system

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Nitrate leaching driven by irrigation is a well-known process that can enhance uranium mobilization in saturated aquifer environments. However, elevated nitrate concentrations are frequently observed within the unsaturated zone, the sequential influence of irrigation-induced nitrate dynamics on uranium mobility in this zone remains unclear. The present study aimed to elucidate how sprinkler irrigation influences uranium mobilization through inorganic reactive nitrogen transformations in the vadose zone. A laboratory-scale vadose zone–groundwater system was constructed using 150 cm soil columns designed to represent distinct redox-driven biogeochemical zones [1]. Two hydrological regimes were established: a sprinkler-irrigated system (n = 3) and a rainfed system (n = 3). Pore water samples were collected biweekly from three depths: 10 cm (root zone), 140 cm (capillary fringe), and the groundwater. Results show that the irrigated capillary fringe pore water contained significantly higher uranium and nitrate levels (U: 41.6 ± 3.0 µg L^{-1}, NO_3^--N: 11.1±1.4 mg L^{-1}) than rainfed (U: 21.5±3.3 µg L^{-1}, NO_3^--N: 7.1±1.6 mg L^{-1}). The porewater ammonium concentration was significantly higher under rainfed conditions (NH_4^+-N: 2.1±0.5 mg L^{-1}) than in irrigated (NH_4^+-N: 0.8±0.1 mg L^{-1}) columns. Although groundwater nitrate-N concentrations were similar, uranium concentrations were significantly higher in irrigated (33.8±3.7 µg L^{-1}) than rainfed (26.0±2.3 µg L^{-1}). The study's findings indicate that irrigation practices, particularly pivot sprinkler systems that account for over 72% of irrigated acreage in the United States, may enhance uranium mobilization within the vadose zone and thereby increase the risk of groundwater contamination.

Keywords: Uranium, nitrate, ammonium, root zone, capillary fringe, groundwater

References:

[1] Science of the Total Environment, Yvon Ukwishaka, Daniel N. Miller, Preetismita Borah, Daniel D. Snow, Michael Kaiser, Chittaranjan Ray, David Fleisher, Dennis Timlin, Vangimalla Reddy, Arindam Malakar* (2026), 1015, 181412.