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Boron Isotopes as a powerful tool for Nutrient Source Tracking: A Multi-isotope study of Surface-water in South Florida

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With an extensive 260,000 km² aquifer, Florida possesses abundant surface and groundwater resources that provide fresh water for approximately 11 million residents. However, these water sources are highly susceptible to contamination, posing significant public health risks through exposure to polluted drinking and recreational waters. Key threats to water quality include nutrient pollution, heavy metal contamination, organic enrichment, and bacterial infiltration. Among these, nitrate pollution in surface waters has emerged as an environmental concern at both regional and national scales. Effective management of nitrate pollution requires identification of contamination sources and mitigation of nitrate inputs—a challenge that becomes particularly complex in large, interconnected aquifer systems like Florida's, where contaminants from both point and non-point sources infiltrate the hydrological system. Traditionally, the nitrogen ($\delta^{15}N_{NO3}$) and oxygen ($\delta^{18}O_{NO3}$) isotopic composition of nitrate has been used to trace contamination sources in surface waters. However, due to isotopic fractionation and overlapping source signatures, this method alone is often insufficient for precise source attribution. To refine source identification, we paired $\delta^{15}N_{NO3}$ with boron isotopes ($\delta^{11}B$) in water samples collected from six selected sites. While conventional $\delta^{15}N_{NO3}$-$\delta^{18}O_{NO3}$ isotope pairs suggested multiple potential contamination sources—including manure, sewage, inorganic fertilizers, and even marine nitrate—the $\delta^{15}N_{NO3}$-$\delta^{11}B$ pairs consistently pointed to manure as the dominant source. Additionally, we applied a multi-isotope approach to characterize South Florida's surface waters by analyzing an array of isotopic markers at selected sites. The local surface-water line was established using $\delta^{2}H$ and $\delta^{18}O$ in water, with $\delta^{18}O$ values ranging from 0.94‰ to 2.41‰ and $\delta^{2}H$ values from 10.56‰ to 18.44‰. The $\delta^{18}O$ of dissolved phosphate ($\delta^{18}O_{PO4}$) further supported the conclusion that animal feces were a major source of contamination. Additional isotopic tracers, including $\delta^{11}B$, and $^{87}Sr/^{86}Sr$, revealed distinct variations among sites, suggesting diverse contamination sources and mixing pathways. By integrating multiple isotopic measurements, we established a unique isotopic signature for each water sample, providing critical insights into contamination sources and their hydrological transport pathways. This study demonstrates the power of multi-isotope approaches in water quality assessments and offers a valuable framework for managing nitrate pollution in complex hydrological systems.