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Understanding the redox milieu of uranium in Eastern Karnataka groundwater through isoscapes

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Uranium (U) in drinking water has emerged as a significant concern in India, given its various adverse health effects. A report by the Central Groundwater Board[1] indicates that 12 Indian states have exceeded permissible uranium levels (30 µg/L by the World Health Organization (WHO) and 60 µg/L by the Atomic Energy Regulatory Board (AERB) of India) in groundwater. Groundwater is often the primary drinking water source in these states. A study in Eastern Karnataka found varying uranium levels in groundwater, ranging from 0.5 to 2700 µg/L[2]. Alarmingly, 78% and 66% of the surveyed sites exceeded the WHO and AERB permissible limits, respectively[2]. None of the sampled bore wells were near nuclear facilities or urban waste disposal channels, suggesting geogenic uranium contamination. Uranium's mobility in groundwater hinges on its sensitivity to redox conditions in the aquifer. Reduction of uranium leads to partitioning of ^{238}U in reduced U(IV) solids, leaving the remaining dissolved U(VI) in groundwater enriched in ^{235}U. Additionally, groundwater near U deposits inherits their low U activity ratio ($^{234}U/^{238}U$ <1; typically ~0.9) due to localized oxidation of U minerals, which can effectively be used to trace the local vs. distal U source. Therefore, we developed $\delta^{238}U$ and U activity ratio isoscapes in groundwater collected from private wells (n=50) across Eastern Karnataka, to track the evolution of uranium concentrations within the aquifer. Our measurements indicate a huge variation in U(VI) concentrations ranging from 0.88 to 2720µg/L with south-eastern part showing alarming level of high U in groundwater (> 1000µg/L). Our $\delta^{238}U$ values for the same set of samples range from -0.95‰ to 0.31‰. The $\delta^{238}U$ isoscapes show elevated uranium reduction zones which coincide with uranium hotspots, low nitrate and high manganese concentration in the aquifer in the south-eastern part of Karnataka. This indicates naturally occurring U(VI) reduction as the contaminated water moves through nitrate and manganese reducing conditions. The U activity ratios in the same samples vary from 1.2 to 5.0 suggesting unsupported ^{234}U enrichment, which indicates a distal U source relative to these wells.

[1]CGWB report 2020,GoI, p. 58. [2]R Srinivasan et al., 2020, Current Science, Vol. 121, No. 11.