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# Subsurface Storage and Riverbank Attenuation Control the Fate of Urban Nitrogen Pollution in a Tropical Aquifer (Bauru, São Paulo State, Brazil)

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Rapid urbanization often results in excess nitrogen (N) loading to aquifers, yet the relationship between surface inputs and groundwater quality impacts remains poorly constrained. This study reconstructs a century-scale (1910–2025) N mass balance for a growing urban area overlying the Bauru Aquifer System (São Paulo State, Brazil) to quantify the role of regional lithology on subsurface N contaminant dynamics. A cumulative anthropogenic N input of ~3,400 t is estimated using historical urban growth and sewerage metrics plus Monte Carlo simulations. This modelled load is evaluated against soil core N inventories and hydrochemical and isotopic tracer data ($NO_3^-$, DO, DOC, $SO_4^{2-}$, $Cl^-$, $\delta^{18}O$-$H_2O$). The results reveal a large subsurface N legacy build-up, with around 2,140 t of N retained in soil and groundwater. Notably, 78% of this stored N is sequestered within the deep vadose zone of sandstone interfluve soils (~1,680 t) while 22% occurs as dissolved N in the underlying saturated zone (~460 t). The mass balance further indicates a system-wide cumulative N removal of 37% (Monte Carlo 5th–95th percentiles: 17%–54%). Hydrochemical ($Cl^-/NO_3^-$ ratios, DOC), redox (dissolved $NO_3^-$ and $O_2$), and isotopic indicators ($\delta^{18}O$-$H_2O$ vs. $NO_3^-$) suggest that this removal is concentrated in areas close to the river banks. Overall, the oxidizing conditions of the sandstone soil matrix promote the long-term storage of N, whereas removal via denitrification is restricted to the organic-rich alluvial sediments deposited in the valley bottoms. Because groundwater is a major source of drinking water for the city of Bauru, the balance between N storage in, and delayed release from, the vadose zone is crucial to assessing current and future risks to water security.

