Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.35431

Groundwater Controls on the Legacy of Antibiotics and Pesticides in an Intensive Agricultural Headwater Catchment in Brittany (France)

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The long-term persistence of agricultural contaminants like pesticides and veterinary antibiotics in the environment remains a critical challenge for water resources, particularly in regions with intensive farming practices. This study investigates the occurrence and persistence of these contaminants in a small agricultural headwater catchment (Kervidy–Naizin, Brittany, France), with a focus on the role of groundwater transit times in controlling legacy pollution. Field measurements reveal contrasting behaviors between contaminant classes: veterinary antibiotics were detected only sporadically in surface waters, whereas pesticides, including atrazine, metolachlor, and their metabolites, were widely observed in both surface water and groundwater.Groundwater age was constrained using chlorofluorocarbon (CFC) tracers and integrated into a three-dimensional, physically based groundwater flow model of the fractured crystalline bedrock aquifer. Particle tracking was applied to simulate groundwater transit time distributions (TTDs), allowing direct linkage between observed contaminant concentrations and subsurface flow dynamics under an advective transport hypothesis. The steady-state model successfully reproduces observed groundwater levels and the spatial extent of the hydrographic network. The results demonstrate that atrazine and its metabolites persist in groundwater with mean ages of approximately 10 years, decades after its ban, while metolachlor residues are associated with even older groundwater (>35 years), as inferred from CFC-constrained TTDs. These findings highlight the dominant role of groundwater, governed by aquifer hydraulic properties, in storing and slowly releasing legacy contaminants long after their application has ceased. This study underscores the value of integrating geochemical tracers with groundwater modeling and field monitoring to elucidate long-term pollutant pathways and improve environmental risk assessment.

