Goldschmidt 2026 Abstract
https://doi.org/10.46427/gold2026.35856

Nitrate loading modulates herbicide (S-metolachlor) attenuation under anoxic soil conditions

BASTIEN REDON[1], OLIVIA RENARD[2], KAY KNOELLER[3], MELANIE LONGCHAMP[4], MARIE MORERE[5], RÉMY GUYONEAUD[2], MATHILDE MONPERRUS[5] AND MATHIEU SEBILO[1]

[1]Sorbonne Université, CNRS, IEES, 75005, Paris, France
[2]Université de Pau et des Pays de l'Adour, Institute of Analytical Sciences and Physico-Chemistry for Environment and Materials (IPREM), Pau, France
[3]Helmholtz-Centre for Environmental Research UFZ
[4]Halle Technologique de Formation GESE, Sorbonne Université
[5]Université de Pau et des Pays de l'Adour, Institute of Analytical Sciences and Physico-Chemistry for Environment and Materials (IPREM), Anglet, France

Electron acceptor availability fundamentally structures microbial energy flow in anoxic soils and aquifers. In nitrate-rich subsurface environments, denitrification frequently dominates terminal respiration and defines prevailing redox trajectories. However, whether sustained nitrate-reducing conditions enhance or constrain the attenuation of co-occurring organic micropollutants remains unresolved, particularly for persistent herbicides that continue to circulate in agricultural systems.

We investigated S-metolachlor attenuation under controlled anoxic conditions across contrasting nitrate regimes representative of agricultural subsurface settings: 0.5 mM NO_3^-, characteristic of moderately impacted environments, and 5 mM NO_3^-, reflecting nitrate-enriched recharge zones and agricultural hotspots. Nitrate-free systems were included for comparison. Experiments were initiated at a soil-associated S-metolachlor concentration of 5 μg g^{-1}, representative of recently treated soils, and monitored over one year to resolve coupled nitrate reduction and micropollutant dynamics.

Nitrate reduction proceeded steadily in all amended systems, with progressive ammonium formation and no sustained nitrite accumulation, confirming persistent nitrate-reducing conditions. S-metolachlor attenuation occurred under all regimes, while its magnitude displayed a non-monotonic dependence on nitrate concentration. In nitrate-free systems, approximately 50% of the initially applied S-metolachlor was lost from the soil phase within six months. Under 5 mM NO_3^-, attenuation over the same period reached ~24%. In contrast, systems containing 0.5 mM NO_3^- exhibited the lowest attenuation, with only minor decreases despite sustained nitrate turnover.

This non-linear response suggests that nitrate availability may influence electron allocation patterns rather than exerting a simple inhibitory control. Intermediate nitrate levels may maintain a denitrification-dominated metabolic regime that preferentially channels electron flux toward nitrate reduction, potentially limiting co-metabolic S-metolachlor transformation. In contrast, higher nitrate concentrations did not further suppress attenuation, indicating a more complex control of redox dynamics.

Complementary nitrate compound-specific isotope analyses ($\delta^{15}N$, $\delta^{18}O$) integrated within a mechanistic reactive framework constrained nitrate reduction pathways and electron flow partitioning, strengthening predictive understanding of nutrient–micropollutant interactions in co-contaminated subsurface systems.