The fate of pesticides in soil and aquifers from a small-scale point of view: Does microbial and spatial heterogeneity have an impact?

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Millions of tonnes of pesticides are used each year worldwide in agricultural production resulting in pollution of groundwater aquifers. There is, however, a striking contrast between the input levels (up to several kg per hectare) and the contaminant concentrations detected in groundwater, which are normally in the microgram to nanogram per litre range. Resent research has revealed a large spatial variation in pesticide mineralisation potentials, but little is known about how these variations/heterogeneities affect the fate of contaminants. We analysed how mineralisation potentials of phenoxy acid herbicides (MCPA, 2,4-D) were spatially distributed in soil, subsoil, and groundwater aquifers using a 96-well microplate mineralisation assay. In the top soil, all samples showed rapid mineralisation following Monod mineralisation kinetics. In the subsoil sediments, a more heterogeneous distribution of mineralisation potentials was observed with fewer samples showing rapid mineralisation and more samples showing either slow 0-order mineralisation kinetics or no degradation. A heterogeneous distribution of herbicide mineralisation potentials was also observed in the groundwater sediment showing the most rapid mineralization close to the water table. The impacts of microbial heterogeneity on degradation and leaching of MCPA through the upper meter of subsurface sediment is evaluated with a numerical model. Results show that for reasonably uniform soils, heterogeneity in mineralisation has little effect on leached pesticide concentrations, with results being similar to that from a model with a homogeneous reaction rate. However, pesticide breakthough at high concentrations can occur in cases where there are fast flow pathways in the soil such as fractures or macropores.