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Infiltration and water flow in the vadose zone of two lysimeters covered by a maize plantation: gaining insights using stable water isotopes and modeling

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The increasing application of pesticides for crop cultivation, intended to increase agricultural productivity, may pose potential human health impacts and may also lead to negative effects on soil and groundwater ecosystems. A first step in gaining knowledge on pesticide fate in the subsurface is characterizing water flow processes, where stable water isotopes ($^{2}H/^{1}H$, $^{18}O/^{16}O$) can be used as natural tracers in combination with modeling.

We carried out investigations at two lysimeters containing different soils, which are dominated by sandy gravels and sandy-clayey silt, respectively. In the area of the lysimeters, maize was planted and four pesticides were applied. For three years, lysimeter outflow water was sampled in 1-2 week intervals and analyzed for stable water isotopes, and also pesticide and metabolite concentrations were monitored. Measured stable water isotopes were evaluated using lumped-parameter model approaches (LPM), in order to determine mean transit times of water in the subsurface (T) and the dispersion parameter P_D. Numerical water flow modeling was conducted as well, for verification and in order to simulate water flow dynamics in more detail.

For describing infiltration and thus tracer input to the vadose zone, different assumptions were compared, where a combination of estimated background evapotranspiration (Penman-Monteith approach) and modeled plant water uptake (simulation of maize transpiration) yielded plausible results and a good correspondence to observed evapotranspiration, as obtained from the water balance at the lysimeters. Estimated mean transit time of water was higher for silt (T of 362 d) than for gravel (129 d). The P_D was estimated 0.7 for silt, while it was considered being 0.12 for gravel. The higher T and P_D may be explained by small pores dominating in the silt, which may lead to slower water movement (higher transit time) and a higher tortuosity (increased dispersion) as compared to the gravel soil. Consideration of preferential flow together with matrix flow could describe the flow processes in both lysimeters more adequately (13% contribution of preferential flow for gravel, 10% for silt in a first estimation). Results obtained by the LPM with those from numerical water flow modeling (Hydrus 1D) and water balance simulations (tipping buckets soil water model) showed well correspondence. Water flow characterization using stable water isotopes coupled to LPM application requires a comparatively high number of water analyzes (measured water isotope input and output as a function of time covering several years), however it has the advantage of requiring only two fitting parameters to describe soil matrix flow (T and P_D).