Design and Performance of a Large Modular Zero-Tension Lysimeter for in-situ Water Collection from Preferential Flow Paths in Undisturbed Soils

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Introduction

Various strategies and geometries of sampling devices are used to collect leachate. The typically applied water sampling technique is the suction-cup lysimeter, which is used since more than one century. One of the disadvantages of suction-cup lysimeters is their limited size, which leads to the phenomenon that in heterogeneous or structured soils most of the suction cups are bypassed by preferential flow paths. An alternative strategy is to collect soil solutions passively by zero-tension devices, such as the lysimeters for zero-tension monolith or plate lysimeters.

Zero-tension plate lysimeters have no or small walls and collect soil water only from preferential flow paths or if the soil water above the pan has a positive pressure, i.e., a positive matric potential. In all other cases water will diverge from the pan toward the dryer surrounding soil. This is resulting in a low collection efficiency. However, the collection efficiency of zero-tension plate lysimeters can be improved with larger pan sizes.

In this study we investigate the performance of a new lysimeter type we carried out several 2D steady state water flow simulations with the Richards equation. The hydraulic functions, parameter combinations and infiltration intensities are listed in Tab. 1. Additionally, the transport of a non-reactive solute was simulated for the heterogeneous standard case.

Results

With this modular technique, which resembles a horizontal sheet pile wall, it is possible to install lysimeters of almost arbitrary width. In our field study, we installed lysimeter plates with an area of 125 by 125 cm. The plates had a decline of approximately 5% toward the pit, which was then re-filled. From there they drained into a stainless steel trench, also filled with the quartz gravel, that lead into a collection vessel (Fig. 2).

Infiltration intensity was 4.0 cm d\textsuperscript{-1}. The transport of a non-reactive solute was simulated for different parameter sets. The results show that the collection efficiency increases with increasing lysimeter size, infiltration rate, and lysimeter width. However, the collection efficiency is highly dependent on the soil hydraulic properties, infiltration rate, and lysimeter size.

Conclusions

We present a modular system that allows large area lysimeter plates to be installed under undisturbed soils. Such large sampling devices are necessary if preferential flow paths are present in soils.

We conducted a numerical 2-D simulation study using homogeneous and heterogeneous soils to investigate the influence of the lysimeter on the water flow field in the soil, and thus the representativeness of the measurements. The results show that the collection efficiency is highly dependent on the soil hydraulic functions, infiltration rate, and lysimeter size.

The collection efficiency increases with increasing infiltration intensities and lysimeter width.

Hydrogenity of soil hydraulic properties results in a network of flow channels that may either hit or bypass small sampling devices.

Tracer transport simulations with an inert solute in a heterogeneous medium show that the solute breakthrough through into the lysimeter occurs slightly retarded as compared to the free soil.

Due to their size the large plate lysimeters average the breakthrough over a large area, and thus give more representative information about the solute flow on the plot scale as compared to single point measurements.