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Micro push-pull tests under unsaturated conditions: A new technique to investigate rhizosphere processes

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The rhizosphere differs in many aspects from the bulk soil. The growth of roots or uptake of water by plants alters directly the physical properties of the rhizosphere. Root activities such as absorption, respiration or exudation can change many chemical properties in the rhizosphere. The aim of this study is to develop a new micro technique that allows studying rhizosphere processes at microscopic scale in-situ. Our goal is to combine the technique of micro-suction cups with that of push-pull tests, creating a miniaturized system that is applicable to study not only concentrations but also reactions and exudation rates in the rhizosphere under conditions as undisturbed as possible. Push-pull tests have been used extensively on a larger scale for the investigation of chemical, physical and biological pollutant transport and transformation processes in aquifers. In a push-pull test, a solution containing reactive and non-reactive tracers is injected into a porous medium. After a defined time the test-solution/soilwater mixture is then extracted back from the same location.

At first, we developed and validated a micro push-pull test procedure that works under saturated conditions in sand-filled boxes. It was possible to inject about 250 μl solution and extract 850 μl solution at a low and constant injection/extraction rate. The data were analyzed and successfully modeled considering advection, dispersion and molecular diffusion. Tracer concentrations of the extracted solution could be very well predicted without using any adjustable parameters. Molecular diffusion was found to play a significant role in determining the shape of the extraction curve. In a subsequent experiment using this technique, it was possible to quantify the degradation rate of citrate injected into a water-saturated, sand-filled box inoculated with denitrifying bacteria. The new technique thus proved to be an adequate tool to observe local biodegradation processes in situ.

Now, we are investigating how the technique can be adapted to unsaturated porous media. A critical point here is the rate of solute injection. The water content close to the injection point should not be increased too much, as e.g. biodegradation rates are sensitive to the moisture content. Not less problematic in unsaturated conditions are the extraction rate and volume. If extraction rates are too high the medium quickly runs dry at the extraction point. Therefore, a compromise has to be found between more data points to determine reaction rates and extracting a minimal volume of soil solution. We carried out a series of unsaturated push-pull experiments adjusting the water potential of the porous medium at different values. The experiments so far gave promising results even at a water saturation of less than 45%. Again the experimental data could successfully predicted by our model. The results thus show that the technique has the potential to become very useful to study the behavior of exudates and solutes in situ under real rhizosphere conditions. In a next step, the method will be used in presence of plants.