Introduction

Transport and retardation of chemical species in soils is currently observed by input-output methods, like recording of break-through curves, and interpreted with the aid of process-simulations, based on highly-resolved structural information, spectroscopic methods and batch experiments. PET provides a direct quantitative observation method for propagation of compounds labelled with a PET-tracer, at intermediate resolution and molecular sensitivity.

In the framework of this SPP, PET serves as a means for verification of CT-based process simulations, determination of process-dependent effective properties, and to unravel the fate of organic pollutants, nutrients and biomass, as far as adequate labelling methods are available.

Principle Techniques

- Cyclotron-production of appropriate positron-emitting radionuclides and labelling of the substance.
- Injection of the labelled substance into the sample.
- After a slowing-down length of roughly 1 mm a positron annihilates in contact with an electron by transmitting two antiparallel photons at 511 keV. These two photons are detected in coincidence and position and time of the events are stored („small-animal“ PET-scanner „ClearPET“).
- Coinciding events define a line of response (LOR). The tomogram is reconstructed from about 10^7 LORs, considering a number of corrections (e.g. absorption of photons).
- The tomograms are quantitative with respect to the tracer concentration. Errors are caused by artefacts due to deficiencies of the correction and reconstruction algorithms.

Application Examples

The transport of a conservative tracer (0.01 M [18F]KF, 65 MBq) through a soil column (diameter 50 mm, length 207 mm) was observed with PET. A tracer pulse of 5 ml (duration 3000 s) was injected into the steady flow (0.1 ml/min) of carrier solution. This example is clearly affected by superficial flow along a small channel – a rather frequent observation, which hardly can be clarified with input-output methods. However, a diffusive front evolved from tracer effusing out of the channel. Segmentation of the tomogram yields quantities like effective volume and residence time distribution.

Special Requirements

Sample preparation

- maximum sample diameter 210 mm
- adjustable field of view (FOV):
  - diameter: 77.5, 93.5, 135, 163 mm
  - length: 100 mm (extendable)
- presently horizontal sample orientation (tilting system in construction)
- maximum resolution 1.3 mm
- labelling with appropriate positron-emitting radionuclides (e.g. 11F, 124I, 64Cu, 11C, 22Na; activity: 1 to 50 MBq)
- detection limit in the range of picoMoles/l
- injection of labelled compound
- spatiotemporal quantitative observation of tracer propagation
- maximum observation time is limited by radioactive decay
- minimum frame rate 1 min
- CT-images desirable as reference
- low-density sample containers preferred

Reference