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# Water table fluctuation effects on solute transfer times

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In catchments with fractured basement, the shallow groundwater that develops and fluctuates in the weathered material contributes to 95% of the solute fluxes in the stream. In order to study the mechanisms responsible for the solute transfer from the top soil layer to the groundwater, applied tracers (bromide, deuterium) along with natural anion concentrations have been analysed in soil water and groundwater in a 10*12m plot in the Kerbernez agricultural catchment (western France). The plot was located in the plateau area and equipped with 6 tensiometers, 18 ceramic cups from 0.25 to 2.5 m and also 7 piezometers from 3 to 20 m allowing to measure the pressure potentials and to collect water in the unsaturated zone (0-2 m), the water table fluctuation zone (2-9 m) and the permanently saturated zone (>9 m). The water samples were collected twice a month and analysed for nitrate, chloride, sulphate, bromide and deuterium concentrations over 2.5 years.

From the field tracer experiment results, three types of porosity region can be identified and quantified: i) the slow and mobile region, ii) the rapid and mobile region and iii) the immobile region. Most of the Deuterium and bromide tracers were transferred slowly at velocities lower than 5 m per year. In regards of the water drainage rate and the velocity value, it means that this slow transfer occurred through 25 % of the bulk volume. However the bromide tracer experiment revealed also that small quantities of tracer were transferred rapidly within the storm period at 35 cm $h^{-1}$ down to the water table. From the analysis of the water table reactivity and bromide rapid transfer, the rapid and mobile region was estimated as 3% of the bulk volume. The rest of the porosity (14%) was the immobile region exchanging solute with the mobile regions by molecular diffusion.

The groundwater water chemistry was characterised i) by high and almost constant anion concentrations in the deepest points (-15 and -20 m below the soil surface) and ii) by a high variability of these concentrations in the water table fluctuation zone. The latter variability followed a similar pattern each year, i.e., a progressive increase of the concentrations from the late fall to late winter. From the field tracer experiment results, assumptions on the processes controlling the time and temporal variability of the groundwater can be proposed. During the high drainage period, the mobile region was at or near saturation, so that low solute rainwater was transferred rapidly through the highly mobile region leading to (i) the saturation of the whole porosity making the water table increase and (ii) low concentrations in the recently saturated piezometer (10 mg $l^{-1}$ $Cl^{-}$ at 5 m). Then mixing processes between rich solute water in the immobile and mobile regions and poor solute water in highly mobile region occurred leading to a progressive increase of the anion concentrations up to 30 mg $l^{-1}$ $Cl^{-}$ in the 5 m piezometer. The low variability in the natural anion concentrations in the permanently saturated zone (-15 and -20 m) showed that lateral flows were dominant and transferred water and solute downslope through the highly mobile zone of the water table fluctuation zone.

This work shows clearly that the water table fluctuation zone is a mixing zone where water flows laterally or vertically depending on the fluctuation frequency and amplitude. It shows also that at the hillslope scale, the groundwater can be divided in two regions, one with rapid flow just below the water table and a slow flow region deeper in the groundwater. Numerical analysis have been undertaken in order to asses the effect of water table fluctuations on the groundwater chemistry and on the solute transfer times at the hillslope scale.