

## Hydrochemical processes in sahelian microdunes: a study using tracers under simulated rainfall

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### Introduction

Soil surface sealing is a common feature of most soils in arid and semiarid regions. It reduces infiltration rate, triggers runoff, and hence increases soils erosion. In the sahelian zone of Burkina Faso, overgrazing and extension of cultivated areas aggravate erosion. Preservation of non-degraded surfaces is crucial in this environment. Aeolian deposits (sandy microdunes) are units where infiltration of water is still significant. They are very important for biomass production. However, these units are subject to livestock overgrazing.

The aim of this study is to improve the understanding of water and solute transport in microdune soils during storm events. Microdunes usually overly haplic solonetz (FAO classification) and are constituted of more or less permeable microlayers. Several questions arise concerning pathways of water and solutes. Do lateral subsurface fluxes through the microdunes exist? Does rain water (new water) mix with the water already present in the soil (old water)? What are the contributions of surface and sub surface flows in the transport of chemically dissolved compounds? Is solute transfer coupled with chemical reactions?

### Materials and methods

The study area is located in the north of Burkina Faso (14°00'20'' N, 0°2'50'' W). It is a degraded watershed, overgrazed by livestock. The climate is of the sahelian type, with a single rain season. Average annual rainfall at the city of Dori is 512 mm. Two non-cultivated soil surfaces are present. The first is the erosion crust, which has formed a smooth surface sealed with finer particles; it has no vegetation cover and shows low infiltration capacity. The second is a sandy aeolian deposit surface, which is more permeable. Measurements were made on the border of a selected microdune composed of two main horizons (Figure 1). The first (about 5 cm deep) corresponds to recent loose sands. The second horizon lies over a silty-sand massive crust.

We used oxygen 18 and chloride as tracers. Simulated rains were used to circumvent the problem of geochemical variability of natural rainfalls. The geochemical signature of the simulated rain is known and does not vary over time. A field sprinkling infiltrometer, produced rainfalls on a 1m<sup>2</sup> experimental plot delimited by a two-level setting. The first level allows surface runoff to be measured and sampled, while the second collects subsurface flow (Figure 1). The simulation were carried out using water with a chemical composition comparable to that of natural precipitation and enriched with chloride and <sup>18</sup>O.

Water samples were taken at 5 to 10 minute intervals throughout each simulation for chemical and isotopic analysis. A cumulative sample of rain was collected at the end of rainfalls using a

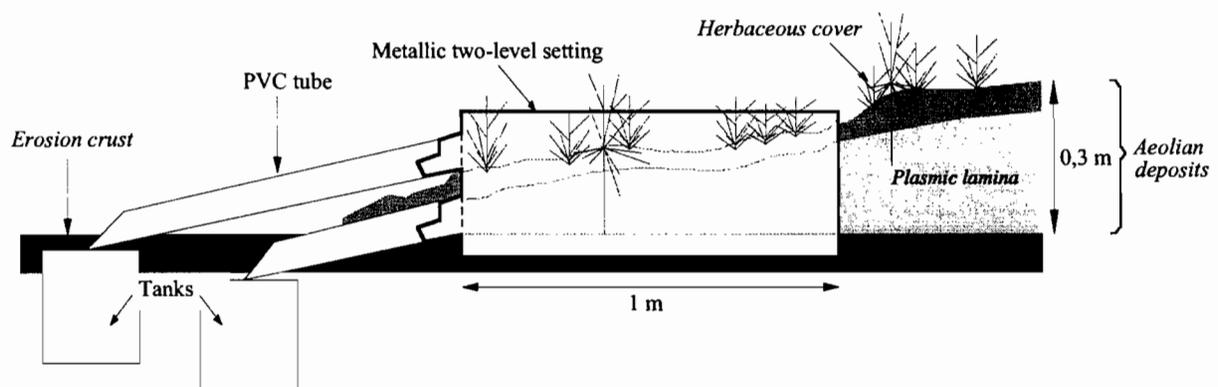
rain gauge located near the plot. Temperature, electrical conductivity and pH were measured in the field. After microfiltration (0.2  $\mu\text{m}$ ),  $\delta^{18}\text{O}$  and the total concentration of alkalinity,  $\text{Cl}^-$ ,  $\text{SO}_4^{2-}$ ,  $\text{F}^-$ ,  $\text{NO}_3^-$ ,  $\text{Ca}^{2+}$ ,  $\text{Mg}^{2+}$ ,  $\text{Na}^+$ ,  $\text{K}^+$  and  $\text{Si}$  were measured in the laboratory.

These data were used as input in the AQUA ion-pair model for calculating equilibrium pressures of the  $\text{CO}_2$  and the saturation index of the solutions with respect to specified minerals (*e.g.* calcite, fluorite, gypsum, silicates). A non reactive mixing model involving two reservoirs and one artificial tracer was then used to estimate the contribution of "new" and "old" water to surface and subsurface flow.

## Results and discussion

Surface runoff occurred after approximately 5 minutes of rain. The chloride concentration of surface runoff was greater than that of rainfall. This difference was due to a 5 % contribution of pre-event water. This result shows that surface runoff isn't only composed of Hortonian overland flow. Soil surface roughness is the probable cause for the old water contribution. Subsurface flow and surface runoff began simultaneously. Proportion of the subsurface flow in the total flow ranged from 30 % at the beginning to 5 % at the end of the event. At the beginning of the simulation, subsurface  $\delta\text{O}^{18}$  and chloride concentrations were similar to those of pre-event water. As the rainfall continued, chloride concentration increased while  $\delta\text{O}^{18}$  decreased rapidly to levels close to new water values. These results prove that subsurface flow is composed of both old and new water. By the end of the rain simulation, a small fraction of old water still remained in the subsurface flow, probably due to the persistence of a small immobile water fraction in the soil.

The concentrations of chemical compounds decreased in surface water as well as in subsurface water, except for fluoride and silica in subsurface water. The equilibrium pressure of the  $\text{CO}_2$  decreased to a level lower than the atmospheric one. The difference between measured concentrations and concentrations computed with the mixing model highlighted strong chemical soil/water reactivity. The calcite dissolution which consumes  $\text{CO}_2$ , and the cation exchange dominated whereas the dissolution of fluorine, silicate and gypsum appear secondary. Reactive mineral stocks are weak and become exhausted quickly, especially in the surface flow. For some of them, results show a kinetic effect.



**Figure 1 - Soil profile and border setting**