

Temporal variations in water quality during stormflow in a rainforest catchment: exchanges with vegetation and soil mineral reactions along water flowpaths

C. Grimaldi¹, M. Grimaldi², T. Bariac³, J. Boulègue⁴

¹ INRA Sol-Agronomie-Spatialisation, 65 rue de Saint Briec CS84215, 35042 Rennes Cedex, France

² IRD, FCAP, UR 064 Biodiversité et fonctionnement du sol, Belém, Brésil

³ UMR 7618 CNRS-UPMC-INRA, Laboratoire de Biogéochimie Isotopique, Jussieu, Paris, France

⁴ UPMC-CNRS UMR 70-47, Laboratoire de Géochimie et Métallogénie, Jussieu, Paris, France

The chemical composition of stormflow water at the outlet of catchments is frequently used for the separation of flood hydrograph data, certain chemical elements being tracers of various contributing compartments that feed the flows towards the outlet. Reciprocally, when the hydrological functioning of a catchment is known, the chemical composition of water at the outlet provides information on the biogeochemical processes taking place in these reservoirs. These processes relate to exchanges with the vegetation or mineral transformations in the soil. Their study on the scale of the storm event supplements our knowledge of nutrient cycling, which is generally estimated over long scales of time, as knowledge of mineral equilibria that are usually studied outside the context of rainy episodes. In fact, the export of nutrients during storms occurs by overland flow, and the mineral reactions vary according to the conditions of renewal of the soil solution.

The present study was carried out on a small catchment area of 1.6 ha under humid tropical forest in French Guiana (catchment B of ECEREX operation). The pedological cover, developed on schist, is made up of oxisols upslope, while 90% of the remaining area is covered by ultisols, which exhibit features typical of waterlogged conditions downslope. Previous work on the structure of the soil and its hydric behaviour showed the existence of two major structural discontinuities producing lateral flows during storm events: overland flow is established on the soil surface at the beginning of spates and at peak discharge; a perched water table is formed at the top of the zone of weathered schist.

The aim of this communication is to interpret the evolution of water chemistry in this catchment during the course of a storm, in terms of exchange with the vegetation and soil mineral reactions. This is accomplished owing to our preliminary knowledge of the flow paths. The event presented here was investigated by a series of tensiometric measurements that enabled us to locate the subsurface hillslope groundwaters. Samples were taken for water analyses under the canopy, at the outlet and in the groundwater bodies. We have carried out separation of the hydrograph using an end-member mixing model with two tracers, ^{18}O and chloride. The present interpretation is based on the following:

The mobility of chemical elements in the litter and at the surface of the soil is estimated by comparing the throughfall with flows at the outlet identified as surface waters.

The processes that take place in the soil are characterized using the evolution of the groundwater or outlet water concentrations with increasing residence time in the soil. The residence time is parameterized by the chloride concentration, which increases by evapotranspiration in the soil. The differences in mobility between chloride and the other elements provide information about processes other than evapotranspiration, which modify the water chemistry according to its origin and residence time in the soil.

At the outlet, the lower chloride contents at the beginning of stormflow and during each peak discharge reflect the arrival of recent water (event water) corresponding to surface circulation. With each decrease in water level, the chloride content increases, thus marking the arrival of increasingly old water (pre-event water). The groundwater bodies in the soil exhibit highly contrasted ages: they are older upslope than downslope, where the component of old water however also increases towards the end of the rainy episode.

The studied chemical elements all participate to differing degrees in the vegetation cycle. Their variable behaviour during the flood gives some information about the biological compartments from which they are released and on the speed of their uptake by the vegetation. In this way, we find that potassium in particular, as well as chloride and aluminium, are leached in the canopy, whereas sodium, calcium, magnesium and silica are leached in the litter. In the soil, potassium is very quickly taken up again by the vegetation even during the rainy episode; the rate of absorption into roots is a slightly less for calcium and magnesium. Only potassium exhibits a rapid removal from the soil solution. The other elements, even those partially absorbed by the vegetation, show an increase in concentration due to evapotranspiration as a function of increasing residence time in the soil.

At the outlet, the pH is buffered at around 4.6-4.8. In the groundwaters, on the other hand, the pH varies between values lower than 4.5, due to the absorption of nutrient cations, and high values up to 5.7, explained by the release of iron into solution.

The silica and aluminium contents are relatively low in water circulating in the subsurface. By contrast, they increase strongly at the outlet as soon as part of the water enters the zone of subsurface flow where mineral dissolution takes place. In terms of flux, however, the quantities of silica exported during this event are equivalent in surface water and groundwater circulating in the soil. This implies that chemical erosion is just as active at the soil surface as in horizons subject to lateral groundwater flows. Even during the storm, the factors controlling mineral reactions in the soil show strong spatial and temporal variations according to the pH and the conditions of groundwater circulation. Thus, we infer a downslope transition from dissolution to neoformation of kaolinite. Sometimes, we can even observe this trend at the same sampling point during a given storm event.

Our results highlight the importance of linking hydrological and hydrochemical studies at the scale of small catchments, to ascertain the diversity of spatial and temporal processes occurring in an ecosystem. In return, a knowledge of water chemistry dynamics during floods can contribute to the search for relevant chemical tracers in hydrology.