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Hyporheic zone as a bioreactor: sediment heterogeneity influencing biogeochemical processes

Nuria Perujo (1,2), Anna M. Romani (2), and Xavier Sanchez-Vila (1)

(1) Hydrogeology Group (GHS), Universitat Politècnica de Catalunya, Barcelona, Spain , (2) GRECO- Institute of Aquatic Ecology, University of Girona, Girona, Spain

Mediterranean fluvial systems are characterized by frequent periods of low flow or even drought. During low flow periods, water from wastewater treatment plants (WWTPs) is proportionally large in fluvial systems. River water might be vertically transported through the hyporheic zone, and then porous medium acts as a complementary treatment system since, as water infiltrates, a suite of biogeochemical processes occurs. Subsurface sediment heterogeneity plays an important role since it influences the interstitial fluxes of the medium and drives biomass growing, determining biogeochemical reactions.

In this study, WWTP water was continuously infiltrated for 3 months through two porous medium tanks: one consisting of 40 cm of fine sediment (homogeneous); and another comprised of two layers of different grain size sediments (heterogeneous), 20 cm of coarse sediment in the upper part and 20 cm of fine one in the bottom. Several hydrological, physicochemical and biological parameters were measured periodically (weekly at the start of the experiment and biweekly at the end). Analysed parameters include dissolved nitrogen, phosphorus, organic carbon, and oxygen all measured at the surface, and at 5, 20 and 40 cm depth. Variations in hydraulic conductivity with time were evaluated. Sediment samples were also analysed at three depths (surface, 20 and 40 cm) to determine bacterial density, chlorophyll content, extracellular polymeric substances, and biofilm function (extracellular enzyme activities and carbon substrate utilization profiles).

Preliminary results suggest hydraulic conductivity to be the main driver of the differences in the biogeochemical processes occurring in the subsurface. At the heterogeneous tank, a low nutrient reduction throughout the whole medium is measured. In this medium, high hydraulic conductivity allows for a large amount of infiltrating water, but with a small residence time. Since some biological processes are largely time-dependent, small water residence time results in low nutrient reduction. Moreover, high nitrification and low ammonium concentration in the interface of the two grain-size layers are measured, probably related to high dissolved oxygen concentration at the coarse-fine sediment interface, further promoting accumulation of bacteria and algae. In contrast, the homogeneous tank shows low dissolved oxygen values and high denitrification in depth which could be related to lower overall hydraulic conductivity, as compared to the heterogeneous tank.

The preliminary analysis of our results indicates a key role of hydraulic conductivity on biogeochemical processes in the porous medium but, at the same time that it is strongly interacting with sediment grain-size distribution and the development of biofilm. The final scope of this study is to know the interactions between physicochemical and biological components in sediments in order to understand in detail the biogeochemical processes occurring.