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INVITED COMMENTARY

Hyporheic zone hydrological processes

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Hyporheic zones

Hyporheic zones influence the biogeochemistry of stream ecosystems by increasing solute residence times, and more specifically solute contact with substrates, in environments with spatial gradients in dissolved oxygen and pH. That is a one-sentence summary of the environmental significance of hyporheic zones. In more depth, the biogeochemical implications from 20 years of study of solute transport, retention, and transformations associated with hyporheic zones are well-summarized and well-placed in broader frameworks of surface water–ground water interactions in the recent book edited by Jones and Mulholland (2000).

Hyporheic zones, at whatever scale, are part of a continuum of stream–catchment connections between stream water and soil water, root-zone water, riparian water, quick-flow, delayed-flow, macropore flow, and so on to including base flow. Drawing further distinctions to define hyporheic zones would seem obfuscatory, if not excessive, in a hydrological framework of surface water–ground water interactions such as presented by Winter *et al*. (1998). However, in the framework of biogeochemical function, the matter of scale confounds any attempt at a single definition. In studying the in-stream dynamics of solutes, specifically nutrients and metals, the definition that I prefer of a hyporheic zone is "a subsurface flowpath along which water 'recently' from the stream will mix with subsurface water to 'soon' return to the stream" (Harvey and Bencala, 1993). For studying solute input/output/retention/transformation budgets along the length of a stream, a less hydrologic definition, "the subsurface zone exchanging at least 10% stream water with subsurface water", is most commonly given (Triska *et al*., 1989). When studying the catchment as the source of solutes to a stream, the hyporheic zone is simply "the subsurface interface between stream water and subsurface water", effectively a membrane, often reactive, of no physical dimension (Schindler and Krabbenhoft, 1998).

Hydrological processes

Continuing advances in knowledge of the hydrological processes of hyporheic zones are critical to quantitative analysis of stream ecosystems. I accepted the opportunity to write this Commentary as a means to encourage further studies to meet this need. Across the scales of stream–catchment connections there are challenges. In considering each of the three scales mentioned above, I think of the following as broad challenges for hydrology relevant to hyporheic zone biogeochemistry.

- *Solute dynamics*: The water within a hyporheic flowpath is an evolving mixture of stream and subsurface waters. Each of the waters contribute dissolved gases, dissolved solutes, and possibly colloidal materials. Can we determine the time scales of the physical mixing and transport? Do these time scales control the extent of reactions?
- *Stream transport*: The scale of the individual, definable hyporheic flowpath will typically be far too fine to be the scale used to parameterize the simulation of stream solute transport. What physical and hydrometric properties of a stream–catchment system determine the characteristics of transport within a hyporheic zone and can be routinely measured (or 'mapped') along a stream at distances of tens of metres, hundreds of metres, or a kilometre?
- *Catchment sources*: The mechanisms of streamflow generation (the quantitative specification of how and when water travels from a catchment to a stream) remain elusive. The questions of how and when solutes travel from a catchment to a stream are compounded by the potential for reactions across the hyporheic interface. We need to further our understanding of flow in the hyporheic zone from the catchment perspective as well as from that of the stream.

Hyporheic zones form a connection of the stream to its catchment in manners distinct from those of a stream cutting through an aquifer from which ground water discharges into the stream much as water from an array of pipes. Over a substantial span of scale, the common element in the challenges I have suggested is that the transport of solutes — by water — between biogeochemical environments is fundamental to the function of hyporheic zones.

References

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