“Clogging layer” at regulated river beds - implications for river-groundwater exchange

Dmytro Siergieiev[1], Angela Lundberg[1], Anders Widerlund[1] & Björn Öhlander[1]
Dep. Civil, Environ. & Natural Res. Eng., Luleå University of Technology

BACKGROUND

Within the EU-project GENESIS (2013), aiming to provide scientific basis and technical guidance for the update of the EU Groundwater Directive, Luleå University of Technology is investigating possible effects of hydropower regulation on surface water (SW)- groundwater (GW) exchange. The study compares SW, GW and hyporheic processes for the unregulated Kalix River and the regulated Lule River. Hydropower has long been regarded a fairly green energy source but today negative effects have become obvious (Renöfält et al. 2010).

The hyporheic zone (HZ) accommodates most of the SW-GW exchange of solutes just beneath and along a river, dampens heat fluxes, processes pollutants and is essential for ecosystems.

CASE STUDY

The study observes SW and GW (in wells orthogonal to the river) at one site in each river. In these, hydrological (water level, hydraulic conductivity, tracer test) and geochemical (temperature, electrical conductivity, water/soil chemistry) measurements were performed during several seasons.

FORMATION OF CLOGGING LAYER

The presence of natural high-flow events in the Kalix River removes fines from the river bed, maintaining good SW-GW connectivity that favours hyporheic exchange (Brunke and Gonser 1997). Altered discharge of the regulated river (reduced flow peaks and velocity, daily discharge fluctuations) facilitated deposition of fine sediments at the river bed forming a “clogging layer” (Blaschke et al. 2003). The bed in the regulated river has two orders of magnitude lower hydraulic conductivity than that at the unregulated site and restricts the SW-GW exchange (Figure 1).

CONCEQUENCES OF REDUCED EXCHANGE

Reduced hydraulic connectivity between SW and GW at the regulated Lule River site suggests decreased fluxes across the river-aquifer interface (Siergieiev et al. 2013), and thus reduced size of the HZ which is not always the case in regulated rivers (Sawyer et al. 2009).

Decreased hyporheic velocities led to increased residence time and favored prolonged contact between water and soil matrix that stimulated biogeochemical transformations. As a result, the electrical conductivity of hyporheic water of the Lule River was higher than that of the surrounding water.

Deteriorated connectivity and extended travel time reduced the dissolved oxygen concentration, which is functionally ecologically essential for hyporheic habitat. In addition, complete consumption of nitrate found at the regulated site, suggests formation of a suboxic zone extending several meters inland which promotes metals release reflected in high dissolved Fe and Mn in the HZ. The conditions of SW-GW exchange control nutrients processing and their export to SW. Thus, the HZ in the Lule River acts as a source of dissolved metals, while in the Kalix River much of the metals are removed by hyporheic processes due to good SW-GW connectivity.

Figure 1. Typical examples of river beds in Kalix (left) and Lule Rivers (right).

CONCLUSIONS

SW-GW connectivity plays an important role for hyporheic exchange and hyporheic water quality. Hydropower regulation in the Lule River has altered this connectivity, which may have far reaching implications for biogeochemical processes in the river.

ACKNOWLEDGEMENTS

The study is funded by EU FP7, Formas and the Kempe foundation.

REFERENSER

Blaschke, A.P., Steiner, K.H., Schmalfuss, R., Gutknecht, D., & Sengschmitt, D., 2003: Clogging processes in hyporheic interstices of an impounded river, the Danube at Vienna, Austria. *Int. Rev. Hydrobiol. 88*, 397-413.

Brunke, M. & Gonser, T., 1997: The ecological significance of exchange processes between rivers and groundwater. *Freshwat. Biol. 37*, 1-33.

GENESIS, 2013. Groundwater and Dependent Ecosystems: New Scientific and Technological Basis for Assessing Climate Change and Land-use Impacts on Groundwater. http://www.thegenesis project.eu. Accessed 20-09-2013.

Renöfält, B., Jansson, R., & Nilsson, C., 2010: Effects of hydropower generation and opportunities for environmental flow management in Swedish riverine ecosystems. *Freshwat. Biol. 55*, 49-67.

Sawyer, A.H., Cardenas , B., Bomar, M., &Mackey, M., 2009: Impact of dam operations on hyporheic exchange in the riparian zone of a regulated river. *Hydrol. Proc. 23*, 2129-2137.

Siergieiev, D., Lundberg, A., Widerlund, A., 2013: Hyporheic water exchange in a large hydropower-regulated boreal river – directions and rates. *Hydrol. Res.* doi:10.2166/nh.2013.011.