Geophysical Research Abstracts
Vol. 15, EGU2013-2287, 2013
EGU General Assembly 2013

On solute residence time in the storage zones of small streams - experimental study and scaling law

Bernhard Schmid
Institut für Wasserbau und Ingenieurhydrologie, Technische Universität Wien, Austria (dr.schmid@aon.at)

Transient storage has a major influence on solute transport in streams, on biogeochemical cycling, water quality and on the functioning of aquatic ecosystems. The first part of the research reported here focuses on surface transient storage (STS) zones between groins along small streams. Such groins are used to protect banks, but also to increase habitat diversity and are, thus, not restricted to large rivers. Repeated tracer dilution experiments on the Mödlingbach, a small stream in Austria some 30 km south of Vienna, have been analyzed to determine the solute residence time between groins and to characterize the exchange processes between dead zones and main stream.

Pairs of related breakthrough curves were measured in main stream and storage zones, resp., and used subsequently to estimate the solute residence time in the surface dead zones under study. Following previous work (Weitbrecht et al., 2008; Jackson et al., 2012) these residence times were, in turn, expressed as

$$T = \frac{W}{k \cdot u} . \frac{h_D}{h_E} \tag{1}$$

with W denoting groin length, u main stream flow velocity, h_D mean water depth between the groins and h_E depth at the interface dead zone - main stream. Coefficient k, finally, is thought to depend on a type of hydraulic radius, R_D = W.L/(W+L), with L denoting the distance between the groins, measured in main flow direction. Using both the Mödlingbach STS zone data and the results of the aforementioned study (Weitbrecht et al., 2008) the following regression equation was derived (h_S denotes main stream water depth):

$$k = 0.00282 \cdot \frac{R_D}{h_S} + 0.00802 \tag{2}$$

The second part of this research focuses on the dependency of solute residence time on flow rate, which is important for an improved understanding of longitudinal solute transport in streams and for the application of mathematical models. The scaling law proposed here is based on a physics-related theory combined with extensive data sets available form a decade of stream tracer experiments on the Mödlingbach stream supplemented with data from Torrente Lura near Milan, Italy. Extensive analysis of tracer dilution experiments from the above-mentioned streams revealed the storage zone residence time to be the parameter with the least scatter and to show a well-defined functional dependency on the flow rate.

Wörman and Wachniew (2007) developed a physics-based expression of residence time in hyporheic transient storage (HTS) zones depending on surface roughness wavelength, hydraulic conductivity, water-depth and flow velocity. Here, that expression has been further developed into a relationship between residence time T and flow rate Q to yield:

$$T = a \cdot Q^{-b} \tag{3}$$

with coefficient a denoting a constant of proportionality and b an exponent, for HTS zones theoretically amounting to 23/40 = 0.575. Simplified analysis of the exchange with STS zones between groins showed that the general form of the law (**??**) still holds, but a lower exponent b $\approx$ 0.40 is to be expected.

Collapsing the Mödlingbach and Torrente Lura residence time data into a single functional relationship of the above form yielded:

$$T = a \cdot Q^{-0.50} \tag{4}$$

with a $\approx$ 48 and b between the theoretical values for HTS and STS zones.

References

Jackson, T.R., Haggerty, R., Apte, S.V., Coleman, A., Drost, K.J. (2012). Defining and measuring the mean residence time of lateral surface transient storage zones in small streams". Water Resources Res. 48, W10501, doi 10.1029/2012WR012096, 1-20.

Weitbrecht, V, Socolofsky, S.A., Jirka, G.H. (2008). "Experiments on mass exchange between groin fields and main stream in rivers". J. of Hydraul. Eng. 134 (**??**), 173-183.

Wörman, A. and Wachniew, P. (2007): "Reach scale and evaluation methods as limitations for transient storage properties in streams and rivers" Water Resources Res. 43, W10405, doi: 10.1029/2006WR005808.