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Effect of Streambed Roughness and Topography on the Solute Transport and Hyporheic Exchanges: Laboratory Experiments

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Hyporheic zones are critical for maintaining river ecosystem as they provide hyporheic and riparian organisms critical solutes, including nutrients and dissolved gases from bedforms to watershed scales. Among the hyporheic driving factors, the streambed topogaraphy is considered as a significant driving factor for hydraulic process in hyporheic zone that has been well documented in the past few decades. Previous research has implied that the rough streambed impact the flow resistance and continuously affect the hydraulic gradient between the river and the streambed. Recent research works focused more on the realistic pressure distribution along the bedform interface (eg. triangular-shaped sand dunes) on a macro level scale, while only few works related to the hyporheic exchanges induced by pore size scaled topography. How and to what extent that pore size scaled bedform would contribute to the total hyporheic discharge is still unclear. Indeed, the mesoscopic uneven topography can disturb the flow regime that near the water-sand interface, for example, it brings turbulent eddies and fluctuating pressure distribution along a rough gravel bed. In our study, a set of flume experiments were setup to examine the pore size roughness impacts on the solute transport and hyporheic exchanges in surface-subsurface system. Six kinds of riverbed sediments with median diameter range from 1.1 mm to 50.2 mm were chosen for comparative analyses. Also, three kinds of triangular shaped bedforms represented by the ratio α (=δ/λ, δ is the amplitude and λ is the wavelength) with value of 0.125, 0.17 and 0.25 were considered as the macro-topography driver variation in our experiments. Our tests revealed that under a flat riverbed condition, the vertical diffusion is the main factor for the solute transport in hyporheic zone, however, the hyporheic exchange rate (represented by the decrease rate in concentration of surface water) is significantly enhanced as the growth of gravel grain size. Results show that the hyporheic exchanges that attribute to pore size roughness is relatively larger under a smaller δ, and less important as macro-topography determine the exchange process. Results also show that the contribution in hyporheic exchanges that induced by pore size topography is proportional to Re(=vd/ν).