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Impact of Reynolds number on tracer spreading in porous media

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Interfacial transport across the free surface flow and obstructed region is critical for understanding the scalar transport and mixing in physical situations such as proximity of open water with vegetation in the aquatic system, sediment-water interface (SWI) in river and estuaries, tree canopies in the atmospheric boundary layer, mixing in coral reef and biofilm formation over biological systems. This interaction occurs over a wide range of Spatio-temporal scales due to fast and slow flow in the free layer and porous media which is determined by the key parameters such as degree of flow unsteadiness and porosity. In these situations, understanding and predicting the spreading of the scalar is crucial for water quality assessment and the health of aquatic ecosystems. In this study, we conduct a high-resolution numerical simulation of an array of circular cylinders packed with channels at moderate Reynolds number (Re). As the Reynolds number increases gradually, we observe that particle tends to form coherent structures at the interface as well as filamentation of tracer behind the cylinders. It is worthwhile to note that filaments are a good candidate for mixing as they enhance concentration gradient which is easily erased by molecular diffusion. Breakthrough curves (BTCs) are measured at the midpoint and outlet of the domain to investigate the spreading of tracers using a random walk-based particle tracking method. We found that as the Re decreases, BTCs become broader because the tracer spends a longer time near cylinder boundaries and within the coherent structure before exiting the domain. These BTCs are successfully predicted by the continuous-time random walk model.