Reynolds Number Dependence of Pore-Scale Mixing Mechanisms in Rapidly Pulsed Pump and Treat Remediation

August Frechette and Zbginiew Kabala

Groundwater remediation is challenged by the sequestration of contaminants in poorly connected, or dead-end, pores. In this dead-end pore volume, induced flow cannot penetrate through. Contaminants remain in high concentration due to the slow nature of diffusion into the bulk flow. Removal of contaminants by treatment methods that induce steady flow is lengthy, and therefore costly. Often, these treatment schemes are concluded before contaminants within dead-end pores are mostly removed, leading to significant contaminant rebound post-treatment.

Treatment methods that utilize rapidly pulsed flow have two advantages over methods that utilize steady flow; rapidly pulsed flows reduce treatment times and eliminate contaminant rebound caused by dead-end pores. These advantages are attributed to the two mixing mechanisms that result from a sudden increase or decrease in flow volume: the deep sweep and the vortex ejection. These mechanisms displace fluid in the dead-end pore space, substantially accelerating the rate of contaminant removal from this space. But the ability of these mechanisms to remove contaminants from dead-end pore volumes is highly sensitive to Reynolds number.

Unfortunately, the benefits of rapidly pulsed pumping have not been expressed on scales that well represent field application. Instead, this technique has been investigated at scales ranging from a millimeter to a meter – where the Reynolds number does not vary greatly. If rapidly pulsed flow is to be advantageous over steady flow in application, it is necessary to produce a velocity field that will effectively utilize the deep sweep and vortex ejection mechanisms to access the bulk of the dead-end pore space at a remediation site. In this work, I illustrate the Reynolds number dependence of the removal efficiency of rapidly pulsed flow. This work serves as an example of how to maximize the benefits of rapidly pulsed flow and determine where these benefits spatially cease to exist.

Presenting Author: August Frechette