Experimental approaches to study nanoparticle transport processes: challenges and opportunities

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Laboratory studies examining the transport and deposition of engineered nanomaterials (NMs) in aqueous granular environments have been performed using a variety of NMs and experimental techniques. Packed column studies are the most commonly used technique to investigate particle deposition onto natural or model aquifer grain surfaces and have been used extensively to study a wide range of NMs. The quartz crystal microbalance with dissipation monitoring (QCM-D) is another useful technique for evaluating the deposition and release behavior of engineered NMs on model aquifer grain surfaces. As particles deposit onto the QCM sensor, an increase in mass on the surface results in a measurable decrease in the crystal's resonance frequency (i.e., negative frequency shift). Furthermore, monitoring of dissipative energy losses induced by the deposited NMs can provide information on their coupling with the surface as well as their size and surface orientation. Although QCM-D has been used to gain insight into the transport behavior of different NMs in natural aquatic environments, a number of caveats exist in the interpretation of QCM-D measurements. For instance, positive frequency shifts have been reported which are counterintuitive to the principle of QCM-D as a mass sensor. In particular, the interpretation of QCM-D measurements for aggregated NM systems has proven to be difficult. The opportunities and challenges presented by the different experimental techniques will be discussed.