



Multiple DNA-tracer transport approach for determining aquifer matrix properties in a laboratory 3D aquifer sand tank: a methodical perspective

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Use of environmental or artificial tracers has been an effective approach to characterize groundwater flow and solute transport, tracking pollutant migration and determine travel time. However, availability of a distinctive number of tracers, variability in interaction with the aquifer matrix, and analytical detection limits are namely few of the significant concerns to be addressed and which led us to focus on employing novel DNA tracers.

Besides the quality of being unique, improbably prevalent in nature and environmentally friendly, DNA tracers can be synthesized virtually in infinite numbers of distinct sequences, rendering them a potential candidate for multi-tracer applications for subsurface and groundwater flow characterization. Studies have already demonstrated the potential of DNA tracing in groundwater studies but a blueprint for methodical application and analysis is required.

In this study, we investigate the applicability of DNA tracers in determining hydraulic parameters of a natural aquifer, such as, hydraulic conductivity, effective porosity, dispersivity, and travel time, the most significant characters of a matrix, influencing solute or pollutant transport. In addition, we aim to leverage the applicability of the tracers in terms of minimizing the uncertainty in estimating the parameters.

In order to capitalize on these advantages of DNA tracers with the aim of addressing the aforementioned objectives, this research focuses on employing multiple dsDNA (ds=double stranded) tracers in a 1.3 m long three-dimensional sand-filled aquifer tank. Under forced-gradient water flow conditions, distinctly sequenced, monodispersed dsDNA tracers are instantaneously injected through injection wells, taking into account different scenarios. The scenarios consider different configurations of injection and sampling strategies. Samples collected periodically were subjected to quantitative polymerase chain reaction (qPCR) for DNA concentration estimation. All the silica-encapsulated DNA particles were comparable in size and surface properties.

Individual breakthrough curves from each of the scenarios are carefully analysed for determining water flow and hydraulic properties. In addition, the experiments producing multiple breakthrough curves are cumulatively analysed for obtaining a minimal uncertainty for the parameter estimations.