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Contaminant Transport Analysis in a Heterogeneous Groundwater System under Non-Linear Sorption Using Physics-Informed Deep Neural Networks

In this study, we investigated the efficiency of deep neural networks informed by physics(PINNS) to predict the non-linear advection–dispersion equation (ADE) in a heterogeneous groundwater system subject to flow velocity varying with location. The non-linearity in the governing ADE stems from sorption processes modeled using the Freundlich or Langmuir isotherms, which describe how solutes are adsorbed onto solid surfaces in porous media. PINNs solve the ADE by embedding the physics of the system directly into the loss function of a neural network, allowing the network to learn the governing equations behavior. The main advantage is that PINNs don't require specialized numerical schemes for handling non-linearities, like Picard iteration, because the network implicitly learn sthem during training. In contrast, finite element method (FEM) often requires a linearization technique, such as Picard iteration, to solve the non-linear system. This involves iterating over successive approximations until convergence is achieved. FEM might also use explicit time-stepping schemes, which require careful handling of stability conditions, especially for non-linear problems. Herein, the PINNS solution is compared to the Finite Element method with time-stepping schemes based on explicit methods and Picard iteration, to handle the non-linear system of equations. Many studies have been made to show the highly accurate and reliable solution of FEM, however in this study the FEM solution is used as reference solution to analyses the efficiency of PINNS.

Keywords: Groundwater, deep neural networks informed by physics, heterogeneous, sorption

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