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Effect of soil heterogeneity on the optimal design of in-situ groundwater bioremediation systems

Tinesh Pathania[1], T Iype Eldho[2], and Andrea Bottacin-Busolin[3]
[1]Department of Civil Engineering, Indian Institute of Technology Bombay, Mumbai 400076, India, Email: tineshpathania@iitb.ac.in
[2]Department of Civil Engineering, Indian Institute of Technology Bombay, Mumbai 400076, India, Email: eldho@civil.iitb.ac.in
[3]Department of Mechanical, Aerospace and Civil Engineering, University of Manchester, Manchester M13 9PL, United Kingdom, Email: andrea.bottacinbusolin@manchester.ac.uk

The use of optimization approaches for designing in-situ groundwater bioremediation systems has been demonstrated in a number of previous studies under the assumption of homogenous soil. However, in real applications the soil is typically heterogeneous and knowledge of the spatial conductivity distribution is, to some degree, uncertain. Here, a systematic attempt is made to quantify the effect of soil heterogeneity on the optimal design of in-situ bioremediation systems. To determine the optimal placement of injection and extraction wells within the computational domain, the meshless element-free Galerkin method (EFGM) was coupled with particle swarm optimization (PSO), resulting in a simulation-optimization (S/O) model which is referred to as BIOEFGM-PSO. A hypothetical case study is considered where the design of an in-situ bioremediation system is optimized considering different degrees of heterogeneity of the porous medium. Heterogeneous conductivity fields are generated using a pseudo-random field generator with same mean and varying variance and correlation lengths. The BIOEFGM-PSO model was then applied to the different soil scenarios, and the resulting bioremediation costs were compared. Results show that the optimal placement of injection and extraction wells depends on the soil properties and, on average, heterogeneous soils have higher in-situ bioremediation costs compared with a homogeneous soil with the same mean conductivity. This highlights the importance of considering soil heterogeneity in designing cost-effective in-situ bioremediation systems, and further demonstrates the general applicability of the BIOEFGM-PSO model.