多層次滲透性反應牆系統整治原始污染物與其降解生成污染物共存地下水污染的解析模擬與功能評估

報告者：何佑婕
指導教授：陳瑞昇
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摘要

滲透性反應牆(permeable reactive barrier，PRB)為一被動式現地整治技術，已被證明是一種有效的綠色整治替代方案，可將關切化學污染物的濃度快速降低至數個數量級以下。鑑於許多地下水污染場址具不同空間分佈下多種污染物的化學混合，近年來提出多層次 PRB 整治系統的概念，並建議可取代單一 PRB 系統以提升含水層整治效率。另一方面，使用解析模擬工具對於多層次 PRB 整治系統執行與設計的效率提升非常有助益。為了簡化數學方程式，目前的解析模擬工具大多採用傳輸過程為平衡吸附之假設；然而，實驗及理論研究結果顯示，非平衡吸附過程可能對地下環境中的溶質遷移有重要影響。因此，本研究目的為發展多層次 PRB 整治系統之多物種化學反應傳輸解析模式，可處理地下水污染物及其降解生成副產物組成的化學混合物質；模式發展將同時考慮平衡和非平衡兩種不同的吸附過程。模式發展過程中，將藉由不同傳輸參數組合下解析模式的計算結果與數值模式計算結果比較進行評估，確認解析模式與其對應計算程式的準確性，而開發完成的解析模式將進行非平衡吸附過程之功能評估，探討非平衡吸附過程對多層次 PRB 整治系統中多物種反應傳輸的影響，並將應用於多層次 PRB 整治系統的設計與優化。

關鍵字： 多層次滲透性反應牆、解析模式、非平衡吸附、平衡吸附、化學混合

Analytical modeling and performance evaluation for multi-permeable reactive barrier system for remediation of groundwater contamination susceptible to coexistence of original contaminant and its degradation-related byproducts

Presenter: Yu-Chieh Ho
Advisor: Prof. Jui-Sheng Chen
Date: 2023/11/03

Abstract

Permeable reactive barrier (PRB) system has proven as an alternative passive in situ but effective remediation technique for rapidly reducing the concentration levels of chemicals of concerns (COCs) by up to several orders of magnitude. Given many groundwater contamination problems can have chemical mixture of multiple contaminants with different spatial distributions, a remediation system with multiple PRBs were recently proposed instead of a single PBR system for more efficient aquifer remediation. Simulations using the analytical modeling tools are generally effective for executing frameworks for the design of efficient multi-PRB systems. For mathematical simplicity, current analytical modeling tools are mostly derived assuming equilibrium sorption process. Experimental and theoretical research results clearly indicated that nonequlibrium sorption process could have a profound effect upon solute transport in the subsurface environment. This study is thus designed to develop novel analytical models for multi-species reactive transport in a multi-PRB system used for remediation of chemical mixture comprised of contaminants and their degradation byproducts in groundwater subject to both equilibrium and nonequilibrium sorption processes. The correctness and accuracy of the derived analytical model and its associated computer code will be evaluated through comparisons between computational results obtained from the derived analytical model against those from a numerical model under different transport parameters. The derived analytical model will be used to investigate the effect of nonequilibrium sorption process on multispecies reactive transport in a multiple PRB system, and used for application of optimizing the design of multi-PRB system.

Keyword: multi-permeable reactive barrier, analytical model, equilibrium sorption, nonequilibrium sorption, chemical mixture.