多層次反應牆對於受氯化物污染之含水層整治數值模式與效益評估

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摘要

目前已發展許多原位(in-situ)地下水整治技術，其中滲透性反應牆作為一種有效率、具成本效益及永續性的整治技術，可處理多種類型之污染物。本研究發展了一個數值模式，使用 Visual MODFLOW 針對多層次滲透性反應牆系統整治效益，進行地下水污染物濃度在時間及空間之變化情形評估。本模式以氯化物為單一污染物種，模擬污染物從多個點源釋放並經過研究區域的移動情形，模擬時間約為五年(1800 天)。本研究以活性木炭(AWC)作為反應性材料，進行污染物在無設置反應牆及設置多層次反應牆等不同案例之數值模擬，並將污染物團(plume)有效控制於可接受範圍內，同時亦考慮滲透性反應牆尺寸及連續注水機制等相關參數，以評估多層次反應牆整治效益。結果顯示，相較於單層反應牆或自然衰減系統，多層次反應牆系統更為有效，可大幅降低各監測井內之污染物濃度。較厚的反應牆可增加氯化物吸附作用於反應材料的停留時間，而達到較好的污染移除率；另外，連續注水對於觀測井鄰近區域亦可提升整治效率，然而對於不同的注水率效果有其上限。再者，相較於本研究範圍之最大深度，多層次反應牆系統在較小的深度即可達到最大移除效率。最後，本研究數值模型顯示，鄰近污染源之多層次反應牆系統對於污染團捕獲帶可提供較好的整治效能。

關鍵字: 地下水整治、多層次滲透性反應牆、Visual MODFLOW、活性木炭、連續注入

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Research paper

Numerical modelling and performance evaluation of multi-permeable reactive barrier system for aquifer remediation susceptible to chloride contamination

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ABSTRACT

Many in-situ groundwater remediation technologies have been developed, among which the permeable reactive barrier (PRB) technology has emerged as an efficient, cost-effective and sustainable remediation technique for the variety of contaminants. In this paper, a numerical model is developed, using Visual MODFLOW, to evaluate the performance of a multi-PRB system over the temporal and spatial groundwater quality variations. Model is simulated for a single contaminant, i.e., Chloride (Cl^-), released from multiple point sources, over a hypothetical study area for a period of five years (1800 days). Initially, the model is simulated without any remediation barrier and later multiple barriers, using Activated wood charcoal (AWC) as a common reactive material, are introduced consecutively to contain the plume to a desirable limit. Various parameters, such as the dimensions of the barriers and continuous pumping, are taken into consideration for the performance evaluation of the multi-PRB system. The results indicate that the performance of the multi-PRB system is more efficient compared to the single PRB and natural attenuation system as the concentration in all the wells could be seen drastically declined with the installation of PRBs. Thicker PRB could produce better chloride removal rate due to the increase in residence time for the adsorption of chloride over the reactive media. Further, the continuous pumping would also increase the rate of remediation for the observation wells in its vicinity, however, up to a certain limit. Furthermore, the maximum efficiency of the multi-PRB system can be achieved at a lower depth compare to full study depth. Moreover, the PRBs adjacent to the contaminant source treat the contaminants in the plume capture zone with high efficiency than the far away PRBs. Finally, the numerical model shows that the contaminant plume, containing chloride, is efficiently captured by the multi-PRB system in the proximity of the point sources.

1. Introduction

Recent years have witnessed an increasing concern over the deterioration of groundwater quality due to various geogenic and anthropogenic sources like agricultural runoff, industrial exertions, activated mine drainage, domestic and municipal solid wastes, etc. (Chakraborti et al., 2010; Schipper et al., 2010; Wiafe et al., 2013; Rodak et al., 2014). These sources have caused the emergence of numerous toxic and fatal contaminants in the groundwater like the chlorinated compounds, hydrocarbons, heavy metals, etc., which have gathered worldwide attention (Thiruvenkatachari et al., 2008; Obiri-Nyarko et al., 2014). More than 400,000 sites in the USA have been severely contaminated with toxic metals such as chlorinated compounds and radioactive materials. Similarly, over Europe and Australia, there are well-documented cases of groundwater pollution due to nitrates, hydrocarbons, chlorinated compounds, sulfates, phosphates, etc. (National Research Council NRC, 1994; Thiruvenkatachari et al., 2008; Chakraborti et al., 2010). The increasing concentration of groundwater contamination has not only led it unfit for drinking but also caused an adverse effect on humans, animals, and the environment (Thiruvenkatachari et al., 2008; Suhag, 2016). These severe incidents of groundwater contamination create demand for the development of an efficient groundwater remediation technique to eliminate the higher risk to health and the environment (Suhag, 2016).

Many conventional groundwater remediation techniques have been developed, over the past few decades, among which the pump and treat

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