Three-Dimensional Numerical Modelling for Simultaneous Removal of Multi Contaminants from Permeable Reactive Barrier (PRB): A Long-Term In-situ Aquifer Remediation Study

RAHUL SINGH[1], Akshit Mittal[2], Sumedha Chakma[1], and Volker Birke[3]

[1]Indian Institute of Technology Delhi, Department of Civil Engineering, New Delhi, India
[2]Delhi Technical University, Department of Environmental Engineering, Delhi, India
[3]Hochschule Wismar, Department of Mechanical, Process and Environmental Engineering, Wismar, Germany

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Abstract

The quality of groundwater (GW) has deteriorated rapidly, which causes many serious threats owing to the exposure of many contaminants to the environment and living creatures. In the last three decades, Permeable Reactive Barrier (PRB) has been proven an efficient and well-established in-situ GW remediation technology for treating various contaminated sites around the world. In this study, the long-term performance of an in-situ PRB has been evaluated by three-dimensional numerical modelling using Visual MODFLOW for the simultaneous treatment of three different contaminants, nitrate (NO3-), phosphate (PO43-) and hexavalent chromium Cr(VI), from GW. The selected materials for PRB are considered as a mixture of five different low cost-reactive materials, i.e., rise husk (RH), fly ash (FA), quartz sand (QS), activated charcoal (AC), and activated alumina (AA), in an optimized proportion. Initially, the model has been simulated for a period of 10 years to obtain the natural attenuation of contaminant plume, with NO3-, PO43-, Cr(VI) contaminants, with the aquifer. Further, multiple continuous PRBs have been installed with optimized design and selected material properties. The simulation results show that the PRB is able to remediate the continuous multi-contaminant plume effectively. The interference of contaminants in the PRB performance also indicates a significant factor in the decline or enhancement of PRB performance in the long run. Similarly, the pumping rate in the proximity of PRB emplacement and the ratio of PRB to surrounding aquifer hydraulic conductivity also played a significant role in enhancing PRB performance. The higher the ratio, the larger the plume contaminant passes through the aquifer, which increases the overall removal efficiency of the PRB system. Therefore, the three-dimensional numerical modelling simulation results of the flow and solute transport model following the PRB performance for simultaneous removal of multi contaminants pave the way for opting for an efficient PRB design for the effective and sustainable performance for a variety of aquifers remediation. The model also provides support to build the understanding for avoiding any potential failure after the emplacement of PRB in the field.

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Rahul Singh[1, 3*], Akshit Mittal[2], Sumedha Chakma[1], Volker Birke[3]

[1]Department of Civil Engineering, Indian Institute of Technology Delhi-110016, India; e-mail: Rahul.Singh@civil.iitd.ac.in; chakma@civil.iitd.ac.in

[2]Department of Environmental Engineering, Delhi Technological University, Delhi-110042 India; e-mail: akshit97mittal@gmail.com

[3]Department of Mechanical, Process and Environmental Engineering, Hochschule Wismar, Wismar-23966, Germany; volker.birke@hs-wismar.de

Abstract

The quality of groundwater (GW) has deteriorated rapidly, which causes many serious threats owing to the exposure of many contaminants to the environment and living creatures. In the last three decades, Permeable Reactive Barrier (PRB) has been proven an efficient and well-established in-situ GW remediation technology for treating various contaminated sites around the world. In this study, the long-term performance of an in-situ PRB has been evaluated by three-dimensional numerical modelling using Visual MODFLOW for the simultaneous treatment of three different contaminants, nitrate (NO_3^-), phosphate (PO_4^{3-}) and hexavalent chromium Cr(VI), from GW. The selected materials for PRB are considered as a mixture of five different low cost-reactive materials, i.e., rise husk (RH), fly ash (FA), quartz sand (QS), activated charcoal (AC), and activated alumina (AA), in an optimized proportion. Initially, the model has been simulated for a period of 10 years to obtain the natural attenuation of contaminant plume, with NO_3^-, PO_4^{3-}, Cr(VI) contaminants, with the aquifer. Further, multiple continuous PRBs have been installed with optimized design and selected material properties. The simulation results show that the PRB is able to remediate the continuous multi-contaminant plume effectively. The interference of contaminants in the PRB performance also indicates a significant factor in the decline or enhancement of PRB performance in the long run. Similarly, the pumping rate in the proximity of PRB emplacement and the ratio of PRB to surrounding aquifer hydraulic conductivity also played a significant role in enhancing PRB performance. The higher the ratio, the larger the plume contaminant passes through the aquifer, which increases the overall removal efficiency of the PRB system. Therefore, the three-dimensional numerical modelling simulation results of the flow and solute transport model following the PRB performance for simultaneous removal of multi contaminants pave the way for opting for an efficient PRB design for the effective and sustainable performance for a variety of aquifers remediation. The model also provides support to build the understanding for avoiding any potential failure after the emplacement of PRB in the field.

Keywords: PRB, Groundwater remediation, Numerical modelling, Low-cost materials.