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Remediation of thallium-contaminated groundwater by permeable adsorptive barrier

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Abstract

The deterioration of groundwater quality is a widespread concern mainly originating by accidental discharges and soil/landfills leaching. Permeable Adsorptive Barriers (PAB) represents a challenging in situ remediation technology, which consist of a continuous trench penetrating the aquifer at a full depth. A PAB is filled with an adsorptive material; groundwater flow moves under natural gradient and the remediation naturally occurs.
This paper deals with the application of a PAB for the remediation of thallium Tl(I) contaminated groundwater in Falciano del Massico, Italy. The polluted site is a solid waste landfill, where many wastes were dumped over the past decades, particularly during the crisis of waste and landfill management in large areas of the region of Campania (Italy). Sawdust is chosen as reactive material for PAB, as it showed good Tl(I) removal capacity.
Based on the hydrogeological and geotechnical characterization of the polluted aquifer, a 3D numerical model is developed to describe pollutant transport and adsorption mechanisms onto the barrier. Numerical simulations are accurately performed over a long time span, by means of Computational Fluid Dynamic approach developed in COMSOL® Multiphysics. PAB configuration and design parameters are determined, in terms of location, shape and main dimensions, using a procedure previously developed. Results shows that the designed PAB is effective for the remediation of the contaminated aquifer, being Tl(I) concentration flowing out the barrier always lower than Italian regulatory limit. Furthermore PAB has been demonstrated to be an efficient long term method for groundwater protection.

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Keywords: Permeable adsorptive barriers (PABs); thallium; groundwater remediation.

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1. Introduction

Discharges and landfills leaching from solid waste landfill are often a significant source of contamination both by inorganic and organic compound, causing the deterioration of groundwater quality. The development of efficient technologies applicable to groundwater remediation is a fundamental objective for environmental sustainability, economic and social issues. However, the design and optimization of an effective groundwater remediation is rather complex, involving hydrogeological and geotechnical properties of the polluted aquifer, pollutant properties and costs evaluation. Among the *in-situ* groundwater treatments, Permeable Adsorptive Barriers (PABs) are a suitable technology, assuring both groundwater remediation and cost effectiveness. PABs consist in a trench penetrating the aquifer and filled of reactive material, whose hydraulic conductivity is higher than that of the surrounding soils, so that the contaminated plume moves under natural hydraulic gradient and it is passively treated without external energy inputs [1]. Furthermore, PABs allow to achieve high efficiency and relatively low operating and maintenance costs in the long term period and allow the productive use of the site almost immediately after installation [2]. Clogging phenomena due to salt precipitation are the main disadvantage of PRBs [3].

PABs have demonstrated to be an effective technology for the removal of both heavy metal and organic compound [4-11]. More in general, the wide application of the adsorption process is also due to the possibility of using different kinds of adsorbents, including natural materials, waste materials or by-products [12-18].

Tl(I) is a highly toxic, mobile element in the environment [19-20]; its removal from groundwater has been studied far less than other toxic element, due to the poor sensitivity of the classic analytical methods [21]. The design and optimization of an *in-situ* effective depuration technology must also take into account the hydrological and geotechnical properties of the entire polluted aquifer, the properties of the pollutants and the adsorption properties of the adsorbent.

The aim of this paper is to investigate the effectiveness of a PAB for the remediation of a Tl(I)-contaminated groundwater. A Tl(I)-contaminated aquifer in Falciano del Massico, a town in the north of the province of Caserta (Italy), in an area (known as *Terra dei Fuochi*) was considered as case study. This area was used as landfill in the late 70s and early 80s. Pollutant transport and capture by the barrier were modeled by a 3D COMSOL® Multiphysics code. The design of the barrier was performed by an optimization procedure previously developed [22]. Activated sawdust [23] was considered as adsorbing material and the main barrier properties (i.e. location, orientation, dimensions) were evaluated, in order to keep Tl(I) concentration out-flowing the barrier below the Italian regulatory limit for groundwater, set to 2 $\mu g\ L^{-1}$ (Italian Legislative Decree 152/06). Furthermore, Tl(I) concentration in the water flowing out the barrier was calculated over a long period of time to check for the effectiveness of the technique.

Nomenclature

A	polluted area total extend
a	external specific surface area of adsorbent particles
C	contaminant concentration
C^*	concentration in the liquid phase at thermodynamic equilibrium with the adsorbing solid
C_{soil}	contaminant concentration on the soil
D	tensor of the mechanical dispersion
D^*_d	coefficient of molecular diffusion
D_h	hydrodynamic dispersion coefficient
H	aquifer bed height