Electrochimica Acta 181 (2015) 192–199

Contents lists available at ScienceDirect

Electrochimica Acta

journal homepage: www.elsevier.com/locate/electacta

Feasibility Of Coupling Permeable Bio-Barriers And Electrokinetics For The Treatment Of Diesel Hydrocarbons Polluted Soils

Esperanza Mena Ramírez [a], Cristina Sáez Jiménez [b,1], José Villaseñor Camacho [a,*], Manuel A.Rodrigo Rodrigo [b,1], Pablo Cañizares [b]

[a] Chemical Engineering Department, Research Institute for Chemical and Environmental Technology (ITQUIMA), University of Castilla La Mancha, 13071, Ciudad Real, Spain

[b] Chemical Engineering Department. Faculty of Chemical Sciences and Technology. University of Castilla La Mancha, 13071, Ciudad Real, Spain

ARTICLE INFO

Article history:
Received 16 October 2014
Received in revised form 23 February 2015
Accepted 24 February 2015
Available online 25 February 2015

Keywords:
Electrokinetics
biological permeable barrier
electrobioremediation
polluted soil
diesel hydrocarbon

ABSTRACT

In this study, the remediation of a diesel hydrocarbon-polluted clay soil using an electrochemical-biological combined technology is assessed. The polluted soil was subjected to an electrokinetic (EK) treatment with a biological permeable reactive barrier. A lab-scale electrochemical cell for soil treatment was used. The biological barrier placed in the soil was a biofilm reactor previously adapted for diesel degradation. A batch experiment of 336 h was conducted in a synthetic clay soil spiked with 10 $g \cdot kg^{-1}$ of diesel and a constant voltage gradient of 1.0 $V\,cm^{-1}$. Sodium dodecyl sulphate was used as an anionic surfactant in the cathodic well to allow for hydrocarbon emulsification during the treatment. At the end of the experiment, extreme pH values were observed near the electrodes. However, the pH remained constant at approximately 7.7 in the central biobarrier zone, which allowed for biological processes. Biological growth was observed in the biobarrier, and a part of the biofilm was detached and transported through the soil in both directions. Furthermore, the surfactant was transported across the soil due to electromigration and electroosmosis, which resulted in diesel emulsification. The combination of biological and EK phenomena finally resulted in a homogenous hydrocarbon removal of approximately 27% in the polluted soil, which indicated a 39% removal of the diesel biodegradable fraction. Due to the electroosmotic flow and the biological degradation, some of the water, surfactant and inorganic nutrients were removed from the soil and should be continuously replaced if a long-time experiment is conducted.
© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

The electrokinetic (EK) treatment of polluted soils consists of applying a low intensity direct electric current through the soil between appropriately distributed electrodes. Consequently, different EK phenomena (electromigration, electrophoresis and electroosmosis) occur in the soil when a current is applied, which promotes the transport of ionic and molecular species in the soil, including pollutants, microorganisms or nutrients, and leads to *in situ* soil remediation. Generally, EK technology is specifically recommended for the treatment of low permeability clay soils [1–5]. In the recent years, interest has increased in combining the advantages of EK technologies with other conventional soil remediation technologies to improve remediation efficiency [6]. In particular, one possible technique is the combination of permeable reactive barriers (PRB) and EK treatments *in situ*.

Generally, PRBs are engineered zones of a reactive material that is placed in the direction of groundwater flow to help intercept a pollution plume that is carried within an aquifer by retaining or degrading the pollutants [7]. The subsurface pollution plume can be caused to flow through the PRB using the natural hydraulic gradient or a pump-and-treat method. However, when the soil to be treated has very low permeability properties, the mobilization of the water using this conventional technique is not possible. Thus, when a PRB is coupled with EK technology, the pollutants are driven by the EK mass transport processes described above.

Different materials could be used to build different PRBs that are based on several different mechanisms (reduction using elemental metals, adsorption with porous high-surface materials, ion exchange with resin-based materials, biological degradation, etc.). In particular, barriers based on biological degradation are named biological permeable reactive barriers (Bio-PRB) or biobarriers. A biobarrier is a fixed culture bioreactor that includes

* Corresponding author. Tel.: +34 926295300.
E-mail address: Jose.Villasenor@uclm.es (J.V. Camacho).
1 ISE member.

http://dx.doi.org/10.1016/j.electacta.2015.02.201
0013-4686/© 2015 Elsevier Ltd. All rights reserved.

a porous supporting material and a microbial biofilm attached on its surface. The working principle of a biobarrier is the same as that of a conventional biofilm reactor. In fact, the only difference is that it is inserted in the soil during EK treatment.

Numerous publications are available regarding the use of PRBs [8–13] or biobarriers [14–20] for the removal of heavy metals or organic compounds from polluted soils. However, the combination of the EK and the PRB treatments is much more recent, and consequently, only a limited number of publications are available regarding this topic: some studies are based on using physical and/or chemical mechanisms in the PRB to remove metals or organic pollutants [21–27], while, to our knowledge, no references are available regarding the specific case of combined biological barriers/EK treatment. The combination of biotechnology and the EK phenomena for polluted soils remediation has been called "electrobioremediation" and has been previously studied as another strategy [2,28–40].

In this study, a soil polluted with diesel hydrocarbons is treated using the EK/Biobarrier method. Hydrocarbon soils and groundwater pollution are major environmental problems that are usually caused by a number of anthropogenic activities that are inefficient or by uncontrolled accidents (leaking tanks or ruptured pipelines at service stations or in industrial areas). In this paper, we propose applying the EK/PRB remediation technology by using a biobarrier with a diesel degrading microbial consortia attached on the surface of gravel particles. Because diesel composition is a complex mixture of different hydrocarbons, diesel fuel could be used as a model for studying the treatment of this type of pollution in soils. The most relevant difference between this study and previous studies is the innovative combination of the biobarrier and the EK process for remediating soil polluted with diesel-oil.

2. Experimental

2.1. Electrokinetic installation

The lab-scale set-up is shown in Fig. 1, and was made of transparent methacrylate and divided into five compartments. The central compartment contained the polluted soil in which the biobarrier with the diesel degrading support microorganism was loaded. The pore system of the biobarrier was filled with a Bushnell Hash Broth (BHB) inorganic nutrient solution, a commercial inorganic nutrient salt mixture that was specific for heterotrophic microbial development and was provided by Difco™ (Le Pont de Claix, France). The BHB composition was as follows: 0.2 $g \cdot l^{-1}$ $MgSO_4$, 0.02 $g \cdot l^{-1}$ $CaCl_2$, 1.0 $g \cdot l^{-1}$ KH_2PO_4, 1.0 $g \cdot l^{-1}$ $(NH_4)_2HPO_4$, 1.0 $g \cdot l^{-1}$ KNO_3 and 0.05 $g \cdot l^{-1}$ $FeCl_3$. The diesel-polluted soil was loaded on both sides of the biobarrier and separated from it by 0.5 mm nylon mesh. The biobarrier was 5 cm thickness. The two electrodic compartments were located on one side of each section of the

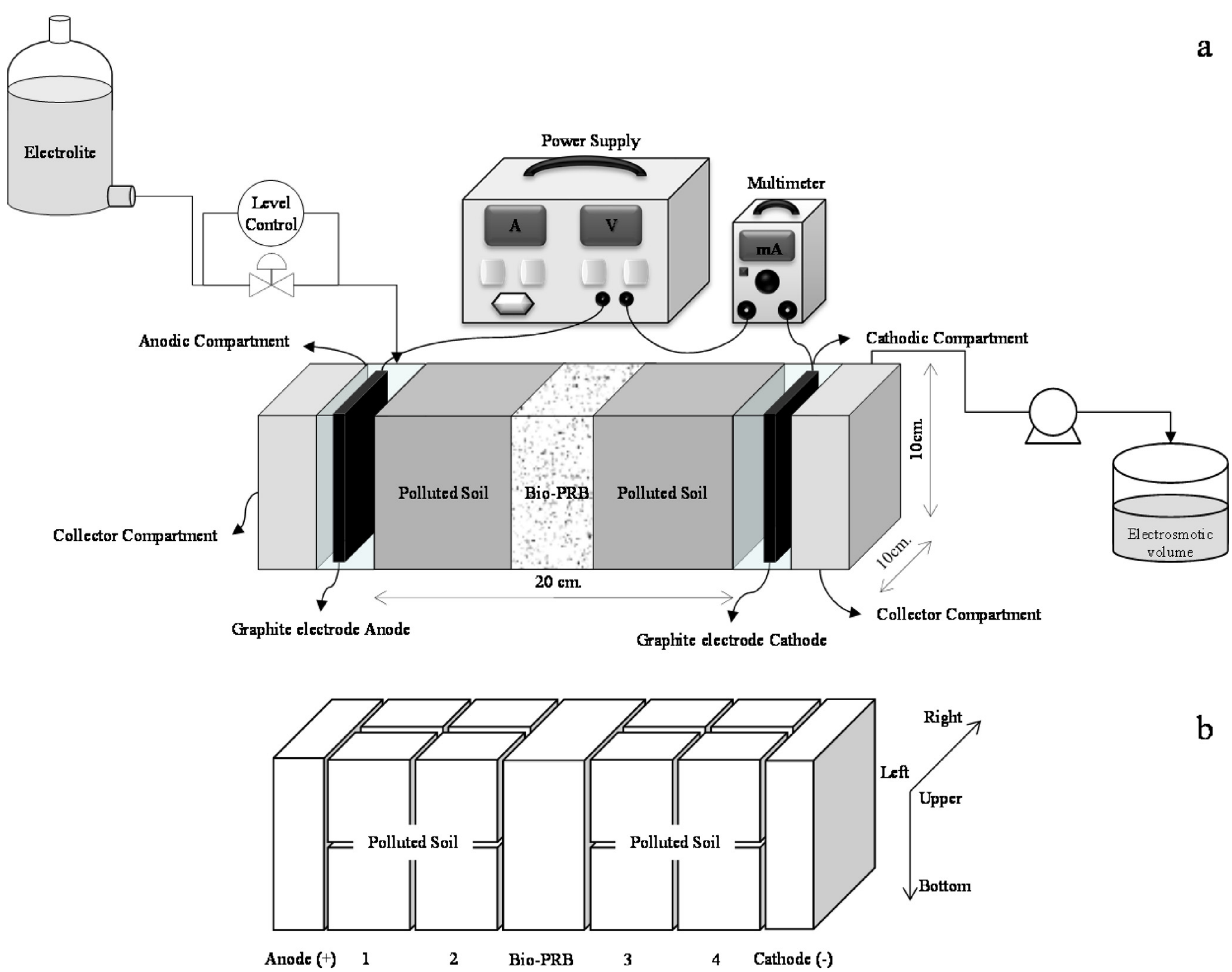

Fig. 1. (a) Bench scale setup scheme. (b) Sampling points guideline.

Download English Version:

https://daneshyari.com/en/article/183487

Download Persian Version:

https://daneshyari.com/article/183487

Daneshyari.com