

Demonstration/Validation of Electrolytic Reactive Barriers for Treatment of Energetic Compounds in Groundwater at the Pueblo Chemical Depot (ESTCP ER0519)

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Introduction

An electrolytic reactive barrier (e-barrier) was installed at the Pueblo Chemical Depot (Pueblo, CO, USA) in early 2006 to intercept a plume of groundwater contaminated with energetic compounds (Figure 1). The concept of an e-barrier is that of a permeable reactive barrier driven by low voltage direct current to affect electrolytic degradation of contaminant compounds.



Figure 1. Installation of e-barrier through a plume containing RDX, 2,4,6-TNT, 2,4-DNT and 1,3,5-TNB

The e-barrier was installed in 15 individual panels consisting of titanium – mixed metal oxide mesh electrodes mounted to vinyl sheet pile (Crane Materials International).

Project Objectives

The primary objectives of the Demonstration/Validation are to provide the information necessary in terms of efficacy and cost to evaluate the potential of e-barriers for treatment of groundwater containing dissolved energetic compounds.

Secondary project objectives are to:

- 1) Evaluate the use of a four electrode set with respect to contaminant flux reduction,

- 2) Evaluate the use of commercially available off-the-shelf vinyl sheet pile as electrode support
- 3) Evaluate the use of a solar power supply
- 4) Provide the data necessary for Pueblo Chemical Depot to evaluate the use of e-barriers as a replacement alternative to the existing pump and treat system



Figure 2. The e-barrier is powered by a 2 kW solar array consisting of 16 PV panels (BP Solar) and 3200 Ahr battery array (MK Battery). Voltage applied to the e-barrier is controlled using DC-DC converters (Vicor). Power consumption by the e-barrier is currently approximately 350 W.

Demonstration Site Description

The e-barrier was installed immediately downgradient of a former munitions washout operation (Figure 3). Local geology consists of alluvial sand overlying the Pierre Shale at a depth of approximately 12 ft below ground surface.

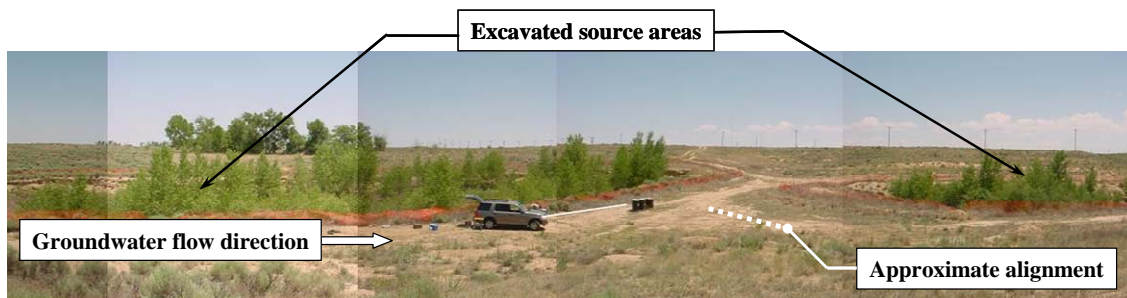


Figure 3. The e-barrier demonstration site is a former munitions washout facility. Washout holding ponds were excavated in 1998.

Hydrology and Water Quality

Groundwater in the area occurs at approximately 10 ft below ground surface. Water table elevation varies approximately 1.5 ft seasonally and flow direction is approximately SSE (Figure 3). MODFLOW simulation of groundwater flow in the area of the demonstration indicated seepage velocities on the order of 0.5 feet per day. Groundwater samples indicate the presence of RDX, 2,4,6-TNT, 1,3,5-TNB, 2,4-DNT, nitrate and ammonium. The site currently operates a groundwater extraction and treatment system located near the property boundary.

e-barrier performance

The e-barrier has been in operation for over 19 months. To date, 3 applied voltages have been tested (2.3V, 3.3V, 4.3V). The barrier is currently operating at 5.3V and approximately 70 A (see Figure 4).

Electrical performance

The solar power array has operated with only minor interruption for the entire demonstration period. Loss of power to date has been associated with DC-DC converter failure.

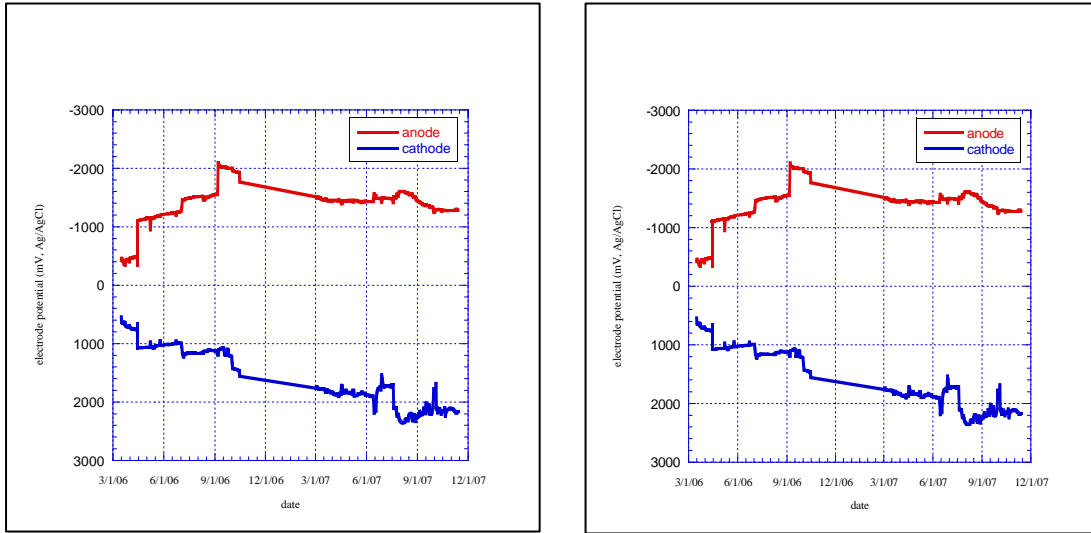


Figure 4. Left: Power density (W/m²) measured over the course of the Demonstration/Validation. Right: measured electrode potentials at the anode (red) and cathode (blue) in the e-barrier.

Contaminant transformation

Transformation of energetic compounds through the e-barrier ranges from over 90% for RDX and TNB to 70% for TNT and approximately 55% for 2,4-DNT (Figure 5). Observed removal is dependent on applied potential with the highest fractional transformation observed at the highest potential tested to date, 5.2 V. Evaluation will continue until fall 2008.

Transformation of contaminant compounds occurs primarily at the electrode surfaces (Figure 6). Downgradient increases or “rebound” in contaminant concentration has been observed and has led to investigation of contaminant storage mechanisms in the demonstration area.

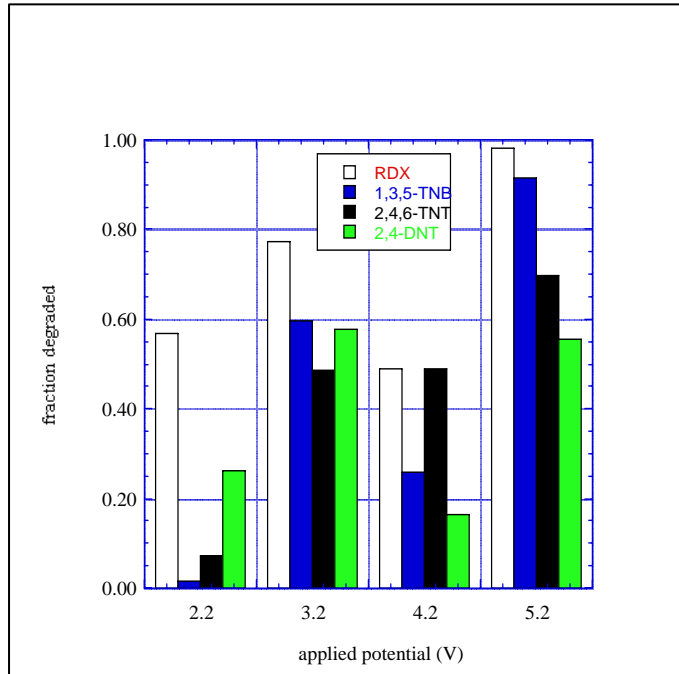


Figure 5. Contaminant degradation as a function of applied potential.

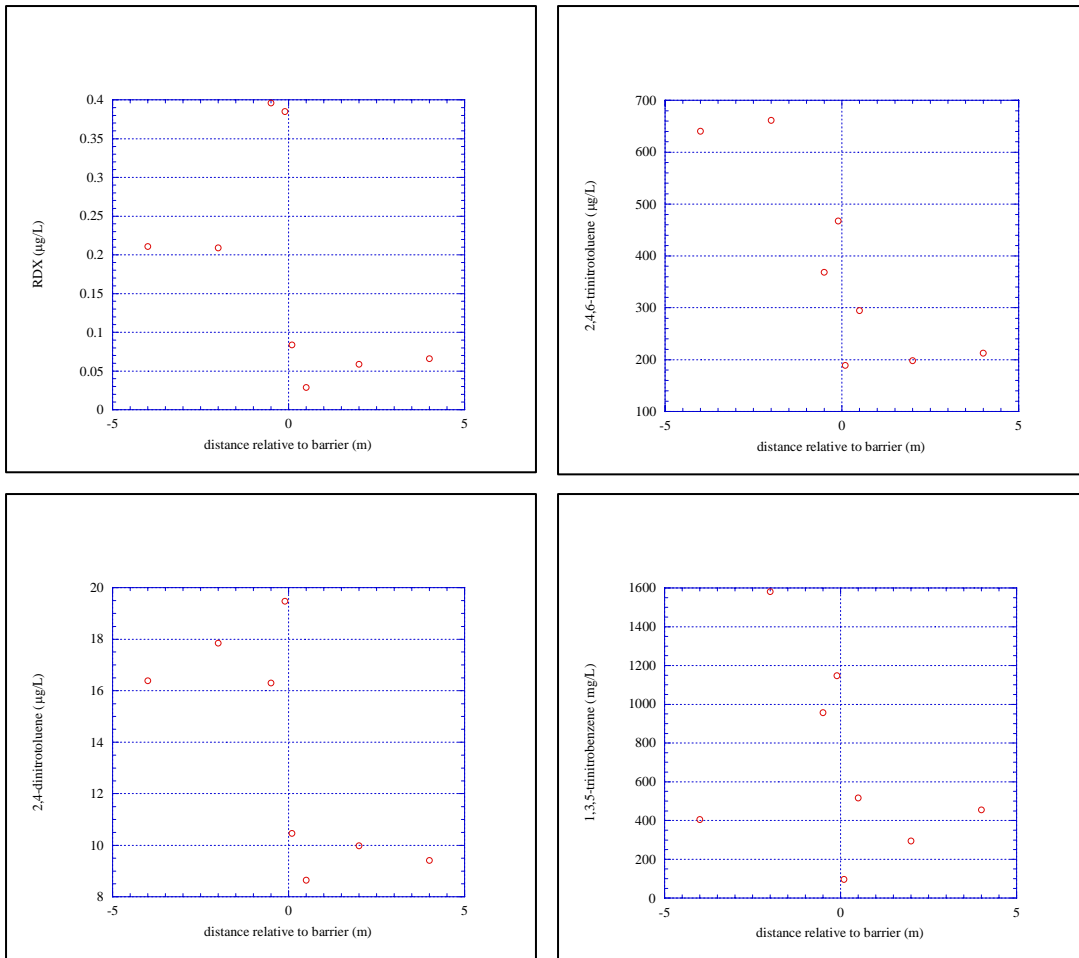


Figure 6. Contaminant concentration as a function of position relative to the e-barrier. The electrodes are located at position 0.

Contaminant Mass Distribution

Performance evaluation indicated downgradient “rebound” in concentration of energetic compounds. To evaluate the possibility of back diffusion of contaminants from low permeability zones, three cores were collected from the demonstration area (Figure 7). The cores were sampled on 2 cm intervals and extracted for concentration of energetic compounds using extraction procedures modified from EPA Method 8330.

The core samples indicated approximately 3.5 m of coarse sand underlain by a shale aquitard (Figure 8). Preliminary analysis indicates that a majority of contaminant mass is stored within the top 20 cm of the underlying shale (Figure 9). This result suggests that back diffusion processes will support elevated plume concentrations.



Figure 7



Figure 8



Figure 8a. Core example from the overlying sand/clay.



Figure 8b. Core example from transition zone between sand and shale



Figure 8c. Core example from Pierre Shale

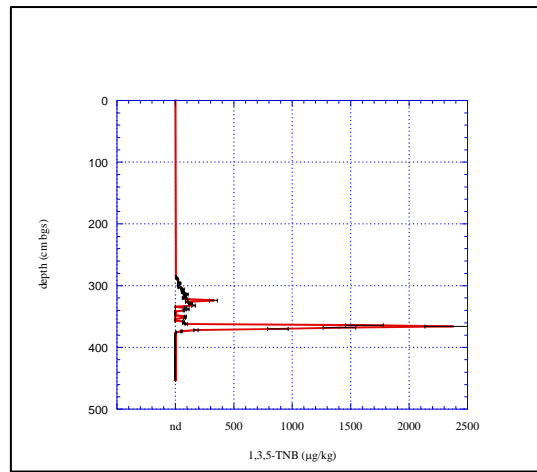
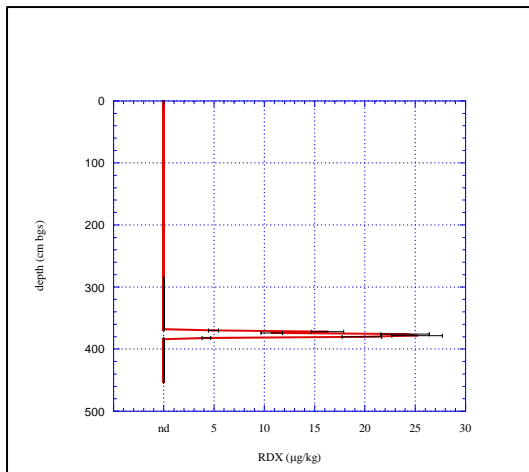


Figure 9. Contaminant concentrations as a function of depth and geology. Peak concentration of energetic compounds is found within 25 cm of the sand/shale contact.

Path Forward

Operation and monitoring of the e-barrier will continue until fall 2008. Final reporting will be completed in spring 2009. Discussion regarding full-scale application of the e-barrier to the energetic plume at the Pueblo Chemical Depot has been initiated.

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