Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Journal of Contaminant Hydrology 76 (2005) 235–249
JOURNAL OF Contaminant Hydrology
www.elsevier.com/locate/jconhyd

# Detection of organic pollutants in sandy soils via TDR and eigendecomposition

A.M.O. Mohamed[a,*], R.A. Said[b]

[a]*Unit of Research Support and Services, Research Affairs; Geotechnical and Geoenvironmental Engineering; Department of Civil and Environmental Engineering; United Arab Emirates University, P.O. Box 17555, Al Ain, United Arab Emirates*

[b]*Unit of Internally Funded Research Projects, Research Affairs; Electrical Engineering; Department of Electrical Engineering; United Arab Emirates University, United Arab Emirates*

Received 1 April 2003; received in revised form 9 September 2004; accepted 22 September 2004

**Abstract**

In this study, organic pollutants in sandy soils are detected using a time domain relectrometry (TDR) probe system and eigendecomposition technique. As a demonstration, four types of organic fluids (motor oil, diesel oil, methanol and ethanol) were examined. Samples were prepared with different combinations of deionized water and organic fluid contents. For each experiment, reflected signals were captured by an oscilloscope, and their characteristics were identified using eigendecomposition technique. Autoregressive modeling and singular value decomposition methods were utilized for calculating the eigenvalues. The most significant eigenvalues were then identified based on their relative magnitude. Experimental results indicated that the presented system is sensitive to both water and pore fluid organic contents. For saturated conditions, signature curves were determined for identification of organic and/or water contents in soil pore fluids.


*Keywords:* Pollution detection; TDR; Eigendecomposition; Eigenvalues and eigenvectors; Autoregressive modeling; Singular value decomposition

* Corresponding author. Tel.: +9713 7051698; fax: +9713 7623154.
*E-mail address:* Mohamed.a@uaeu.ac.ae (A.M.O. Mohamed).

0169-7722/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.jconhyd.2004.09.002

## 1. Introduction

Applications of time domain relectrometry (TDR) in the area of contaminant hydrology have been demonstrated (Heimovaara and Bouten, 1990; Kachanoski et al. 1992; Elrick et al. 1992; Wraith et al., 1993; Vanclooster et al. 1993; Mallants et al. 1994a and b; Sun et al. 2000; Mohamed et al. 2000, 2001, 2002, 2003a and b; Said et al. 2001; Dowding 2001; Mohamed 2002; Mohamed and Hawas 2004; and others). TDR detection operates by analyzing the characteristics of a fast-rising electric potential signal as it reflects at a probing end of a transmission structure (coaxial cable for example) immersed in a sample under investigation. The characteristics of the reflecting signals are highly influenced by the electrical properties of the sample, which are dependent on the physicochemical properties of the pore fluid, soil structure and minerals, initial placing conditions and temperature.

Most of the reported studies (Kachanoski et al. 1992; Elrick et al. 1992; Wraith et al., 1993; Vanclooster et al. 1993; Mohamed et al. 2000, 2001, 2002, 2003a and b; Dowding 2001; Mohamed 2002; Mohamed and Hawas 2004) were carried out on sandy or loamy sandy soils with low clay and silt contents and without distinct macropores. These relatively favorable conditions allowed the researchers to adopt simple hypotheses for the water flow and solute transport, as well as measurement calibration. The success or failure of the TDR technique to accurately predict solute concentration is heavily dependent on the appropriateness of the calibration procedure used. In fact, this is also true for other detection techniques, including the electrical conductivity measurements made using conventional four-electrode salinity probes. In addition, inasmuch as most of the work done was concerned with inorganic pollutants, one needs to investigate the potential application of TDR for detection of organic pollutants in subsurface soils.

Therefore, the primary objective of this work is to demonstrate the ability to detect of organic pollutants in soils by analyzing captured TDR pulse signals using eigendecomposition technique. The proposed technique characterizes the captured signatures of organic and water contents by a number of eigenvalues calculated by autoregressive modeling and singular value decomposition methods. To demonstrate the proposed method of analysis, measurement and analysis of four types of organic fluids (motor oil, diesel oil, methanol and ethanol) were used with different combinations of deionized water and organic fluid contents.

## 2. Theory

### 2.1. Detection by TDR

In brief, a monitoring probe machined from a conducting rod (reference) is connected to a pulse generator and to an oscilloscope via a transmission line (coaxial cables). The oscilloscope is used to acquire the system response through a measurement point on the transmission line. During measurement, an electrical pulse with a fast-rising edge is generated periodically by the pulse generator and launched toward the probe. The pulse signal propagating toward the probe appears on the oscilloscope as it passes the