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# Estimation of Volumetric Oil Content in Unsaturated Soils using Thermo-TDR Techniques

Aoki, S.[1], Arikawa, H.[2], Kohara, M.[2], Ishii, K.[2], and Noborio, K.[2]
[1]Graduate School of Agriculture, Meiji University, Kawasaki, Kanagawa, Japan. s_aoki@meiji.ac.jp
[2]School of Agriculture, Meiji University, Japan.

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Subsurface and groundwater contamination with organic compounds by accidents and activities at gas stations, and various industrial facilities may result in a serious environmental problem. Environmental impact is limited not only chemical, physical, and biological conditions of soil, but also harmful to human health. After a contaminant reached the groundwater, we often notice the pollution of soil and/or the groundwater for the first time. When a pollutant reaches the groundwater, the pollutant spreads along with groundwater flow. Because the contamination spreads in wide areas, its removal becomes very difficult and time consuming. It is important to detect a trace of the pollutant and measure a contaminant concentration in unsaturated soil before it reaches the groundwater. For the early detection of pollution, simple monitoring techniques have been desired. In the present study, we attempt to observe volumetric oil content ($\theta_o$) in unsaturated different types of soils using thermo-TDR technique. The thermo-TDR technique is measurable simultaneously the volumetric water content ($\theta_w$) by TDR, and the thermal property (e.g. volumetric heat capacity) by DPHP (Dual Probe Heat Pulse) method.

The thermo-TDR measurements was conducted on three soils, a volcanic ash soil, a Toyoura sand, and glass beads. The volcanic ash soil was sampled from the surface layer (0-20 cm) of experimental farm of Meiji University, Kanagawa, Japan. Soil samples were air dried, ground, sieved through a 2-mm sieve, and oven dried at 110°C. Known amounts of distilled water, kerosene, and soils were mixed and kept for over 12 hours in sealed plastic bags. The contaminated soil samples were packed uniformly into polyvinyl chloride/metal cylinders with various liquid contents and oil concentration. The thermo-TDR probe was inserted vertically into the soil surface and the $\theta_w$ of the TDR and $C_b$ of the DPHP were measured in an incubator (20°C). We used a three-wire thermo-TDR probe (0.040m long, 0.0075 m spacing, the center rod housing a nichrome heater wire, and the outer two rods containing type-T thermocouples) to measure the soil properties. The volumetric oil content can be calculated as follows (modified from de Vries, [1])

$$\theta_o = \frac{C_b - \rho_b c_s - \rho_w c_w \theta_w}{\rho_o c_o} \quad (1)$$

where $\rho_b$ is the bulk density (kg $m^{-3}$) of the soil, $\rho_w$ is the density of water (kg $m^{-3}$), $c_s$ $c_w$, and $c_o$ are the specific heat capacity (J $kg^{-1}$ $K^{-1}$) of soil solids, water, and oil, respectively. $C_b$ is the volumetric heat capacity of bulk soil (J $m^{-3}$ $K^{-1}$).

Volumetric oil content estimates from the thermo-TDR sensor was compared with controlled volumetric oil content (Fig. 1). For the three types of soils, $\theta_o$ data were distributed randomly along the 1:1 line, indicating that the thermo-TDR technique was able to capture the trend of the volumetric oil content.

*References:*

[1] de Vries D.A. (1963) : Thermal properties of soils. p. 210-235. In W.R. van Wijk (ed.) Physics of plant environment. North-Holland Publ. Co., Amsterdam.

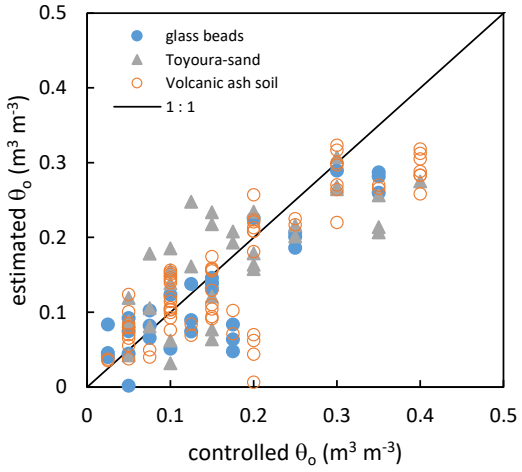


*Figure 1: Thermo-TDR estimated volumetric oil*