DETERMINATION OF TWO-PHASE CAPILLARY PRESSURE-SATURATION RELATIONSHIP

Radka KODEŠOVÁ[1], Svatopluk MATULA[1], Miroslav KUTÍLEK[2], Jana VESELÁ[3]
[1]KPG AF ČZU, [2]NAD PAŤANKOU 34, 16000 PRAGUE 6, [3]CZECH TECHNICAL UNIVERSITY, PRAGUE

Summary, keywords

Results of measurements of capillary pressure-saturation relationships for two two-phase systems (air-water and air-oil) in two soils (loamy sand and silt) are presented. The prediction technique based on the modified Leverett's concept was applied. Partial suitability of tested method only for loamy sand is documented by comparison of scaling factors based on interfacial tension values with the actual scaling factors between two capillary pressure functions.

Immiscible phases, capillary pressure-saturation relationship, interfacial tension, scaling

Introduction

Contamination of the soil and ground water by nonaqueous phase liquid (NAPL) due to waste spills is not only a serious problem from point of view of water quality but also plays important role in protection of soil and its vegetable cover. For prediction of the NAPL transport, mathematical models describing movement of immiscible phases in soil and groundwater are applied. In order to use those models, the relationship between fluid pressure, saturation and hydraulic conductivity must be known. Due to a lack of simple experimental techniques to measure required relationships directly, prediction techniques are commonly used. Parker et al (1987) proposed prediction of capillary pressure-saturation relationship for different fluid combination from measured capillary pressure-saturation relationship for air-water system. Method was based on the modified scaling relationship (Leverett, 1941) for identical porous media. This technique was further tested by Lenhard and Parker (1987), Demond and Roberts (1991), Dane et al. (1992), Bradford and Leij (1995), Hofstee et al (1997) and Liu et al (1998). In spite of that the method was not always successful (Hofstee et al, 1997) and some authors proposed partial improvements of this method (Demond and Roberts, 1991; Bradford and Leij, 1995) the original Leverett's technique is frequently applied.

Methods

Capillary pressure-saturation relationships were measured for two two-phase systems: air-water and air-oil (*Diesel oil*). A sand tank and a pressure plate apparatus were used for determination of 4 drainage air-water pressure curves in loamy sand. The Tempe's cell was used for measurement of 2 drainage/wetting air-water and 1 drainage/wetting air-oil pressure curves in loamy sand; 1 drainage/wetting air-water and 1 drainage/wetting air-oil pressure curves in silt. Curves were fitted with van Genuchten equation (1980). In the cases of multiple measurements single curves were obtained via fitting entire set of data points. Modified Leverett's concept for prediction of capillary pressure functions was applied. Scaling factor determined as a ratio of interfacial tensions (σ_{wa} / σ_{oa}) was used to predict air-water curves from air-oil curves. The actual scaling factors between two capillary pressure functions (air-oil and air-water) were calculated and compared with scaling factors based on the interfacial tension ratios.

Results - discussion

Here we present only resulting scaling factors. Scaling factor evaluated as the ratio of interfacial tensions is the same for both soils. Actual scaling factors were determined for each pair of the correspondent capillary pressure functions. For loamy sand the air-oil drainage capillary pressure function was paired with the air-water drainage capillary pressure function obtained either in the sand tank (ST) and the pressure plate (PP) or in the Tempe cell (TC). Similarly the other pairs were compared as it is shown in the Table 1.

Table 1. Scaling factors

Specification method	Scaling factor
σ_{wa} / σ_{oa}	0.07/0.0225=3.11
Loamy sand, drainage curves ST and PP	3.13
Loamy sand, drainage curves TC	4.61
Loamy sand, wetting curves TC	6.01
Silt, drainage curves TC	1.70
Silt, wetting curves TC	1.80

It is obvious that the interfacial tension scaling factor is approximately the same as the actual scaling factor only for the air-oil drainage capillary pressure function related with the air-water drainage capillary pressure function obtained in ST and PP. For the other pairs the actual scaling factors are either higher (loamy sand) or smaller (silt) then the interfacial scaling factor. The data points for silt created slightly double S-shape curves. If two measurements above an inflection point are ignored, the actual scaling factor (=2.9) is closer to the interfacial scaling factor. The actual scaling factors for the correspondent drying and wetting curves for silt are very similar. The possibility of using one scaling factor for drying and wetting curves estimation is proved in this case. The actual scaling factors for drying curves are smaller then for wetting curve for loamy sand. It should be mentioned that the capillary pressure curves were not determined on one soil sample. Measurements can be influenced by heterogeneities caused by packing of soil samples.

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