

MEASURING THE FLUID CONDUCTIVITIES OF SOIL IN MULTIPHASE SYSTEM

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Introduction

Getting to know the behaviour of non-aqueous phase liquids (NAPLs) is an inevitable precondition for the most precise definition of the existing environmental and human risks and for the efficient remediation of the polluted areas (Várallyay *et al.*, 1996; Soga *et al.*, 2005). Several studies have been devoted to the behaviour of NAPLs in Hungary as well in the recent years (Makó, 2000; Makó, 2005). These laboratory tests can render help for understanding the theoretical bases of the processes taking place during the spread of pollution and provide input data for different computer models. The aim of our experiments was to examine the fluid conductivity of the multiphase (water and NAPLs as fluid phases) Hungarian soils and to elaborate a reliable method for measuring the fluid conductivity of undisturbed soil samples using non-aqueous fluids.

Methods

Three different Hungarian soil profiles were chosen and sampled in order to perform the fluid conductivity experiments. The soil types and the sampled horizons are shown in Table 1. Altogether 11 disturbed and undisturbed samples were collected. The disturbed samples were air-dried, milled and sieved by 2 mm sieve. The most important physical and chemical properties of the samples were determined by generally used soil science methods (Búzás, 1993) (Table 1). The undisturbed soil samples were dried at 40 °C and carefully removed from the cylinders. The dry soil columns were covered and stabilized with synthetic resin (POLIKON P-210 FAXT) to eliminate the flow along the walls during the conductivity measurements. Finally the connecting parts of the permeameter were fixed with the synthetic resin to the samples. The fluid conductivity measurements were carried out with distilled water and NAPL on the soil columns using the falling head method (Klute and Dirksen, 1986.). Three replicates were used for each fluids from the samples and nine measurements were made on each soil column. The NAPL was a non-aromatic distillation product called DUNASOL 180/220 (Makó, 2000). While examining the fluid conductivity capability of systems containing several liquid phases we measured the seepage speed of oil (DUNASOL 180/220) through soil-columns previously saturated with water and the seepage speed of water through soil-columns saturated with oil.

Table 1. Certain characteristic properties of the soil samples

sample sign	site of origin of sample	soil type (WRB)	name and depth of the sampled soil	Sand % (>0,05 mm)	silt % (0,002-0,05 mm)	clay % (<0,002 mm)	bulk density g/cm ³	humus %	CaCO ₃ %
1.	Keszthely	Eutric Cambisols	A 0-25	62,7	14,1	23,2	1,73	1,73	0
2.			B ₁ 25-40	55,1	19,3	25,7	1,66	0,81	0
3.			B ₂ 40-62	51,5	19,2	29,3	1,52	0,81	0
4.			BC 62-87	57,6	16,9	25,6	1,51	0,52	0
5.	Lovasberény	Calcic Phaeozems	A 0-45	20,4	63,3	16,3	1,40	3,19	12
6.			B 45-73	22,0	57,9	20,1	1,27	1,64	26
7.			BC 73-104	26,0	56,7	17,9	1,18	1,13	30
8.	Magyarszombatfa	Gleyic Luvisols	A 0-21	13,2	66,1	20,8	1,59	1,53	0
9.			B ₁ 21-47	7,8	61,3	30,9	1,60	0,60	0
10.			B ₂ 47-79	8,7	61,2	30,5	1,61	0,33	0
11.			C 79-105	10,7	57,3	32,1	1,57	0,36	0

Meanwhile we continuously registered the quantity of liquids seeping through and examined the changes in the speed of permeation depending on the quantity/rate of seepage.

Result and discussion

The test results on the fluid conductivity of systems containing several liquid phases are illustrated in Figure 1. and 2. for the sample of Keszthely. The figures also show the test results for the fluid conductivity of systems with one single liquid phase (for water or oil).

In general it can be stated that in the cases where the samples were first saturated with oil and saturation with water follows afterwards (i.e. oil is displaced by water from the pore space) the liquid conductivity measurable by water is diminishing. The more clay there is in the soil the less the rate of decrease is. The final decreased conductivity is significantly less - with one or two orders of magnitude - than the saturation hydraulic conductivity of the samples. The beginning part of the curves shows however always higher conductivity than the saturated hydraulic conductivity (but not higher than the oil conductivity of oil-saturated samples). We explained these phenomena that at the beginning part of the measurements the infiltrated water pushes the oil phase of the pore spaces in front of itself. This time mostly the oil flows through the samples. After the water pushed out the oil from the larger sized pores, mostly the water phase flows through the samples. The surface of the solid phase are still covered with oil, therefore the pores available for water flow are much tighter than in the case of the saturated hydrologic conductivity measurements. In the mean time, working with clayey samples it is presumable that the surface of the solid phase may locally be connected to the water phase and it may swell as well. That can cause further tightening of the pore spaces (higher decrease in conductivity).

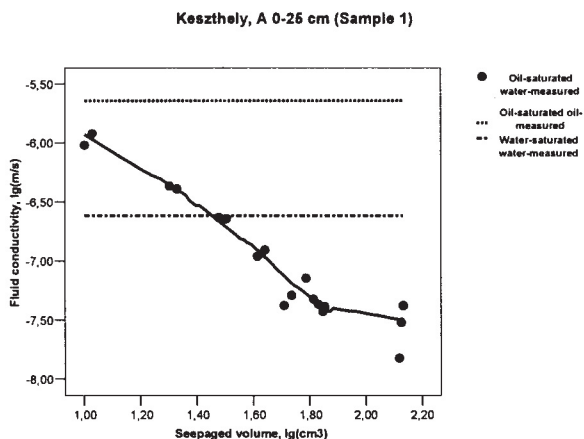


Figure 1: Testing multi-phase fluid flow. A. Fluid conductivity of the Keszthely sample previously saturated with oil and measured with distilled water.

When the pore spaces are first filled with water the oil conductivity of the samples decreases at the beginning. However, we can only rely on assumptions about the later rising phase of the conductivity curves. The explanation for this phenomenon can be the changes in the size of the pores taking place parallel with the gradual water displacement from the solid surfaces: presumably macro-pores are created during seepage and water displacement which result in the increase of the oil-conductivity of the samples with orders of magnitude.

Conclusions

Based on our experiences achieved so far it can be stated that in soil systems containing several liquid phases the degree of conductivity and seepage of different fluids depends in a great extent on the sequence of saturation, wetting with liquids and on the (mainly physical) characteristics of the soil samples.

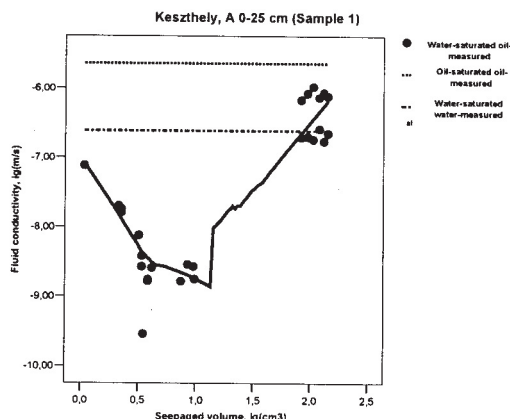


Figure 2: Testing multi-phase fluid flow. B. Fluid conductivity of the Keszthely sample previously saturated with distilled water and measured with oil.

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