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THE IMPORTANCE OF THE POLARITY OF WATER AND THE ELECTRICAL CHARGE OF SOIL UPON THE FLOW OF WATER IN SOIL

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ABSTRACT

The flow of water in soil should be influenced by the negative charge of a loamy or clayey matrix. Such a matrix is influenced by the water content on swelling and shrinking. The latter effect did not allow to measure the first. Therefore the pore system in soil samples with different charge has been kept constant by freeze-drying and the effect of polarity upon flow has been measured by the use of polar (water) and apolar (heptan, air) fluids. With increasing charge of the soil the flow rate of water decreases due to polarity. It is probable that absorption causes the reduction of the flux, that immobile water layers surround the flowing water and that the pressure gradient regulates the relation between the cross-sections of flowing and immobile water.

INTRODUCTION

The liquid phase in the soil is a polar, liquid fluid including ions and reacting with the charged matrix of the soil. This reaction causes deviations from the law of Darcy, which has been attributed to the absorption (ref. 2 and 8) and/or the electroosmosis (ref. 3, 7 and 11). In soil material it was not possible to confirm a flow of water, induced by an electrical potential (ref. 1 and 10). Therefore adsorption should be possible. But the amount of the effect of adsorption upon flow was not measurable, due to the interaction of soil and water. Replacing water by a polar fluid induced shrinking. The pore system changed. My problem was to find a method to keep the pore system unchanged.

MATERIAL and METHODS

The soil material was coherent and varied in cation exchange capacity (table 1). The fluids varied in polarity and state of aggregation (apolar liquid: gasoline, apolar gas: air, polar liquid: water). I took 20 100-ml-cores from each soil. Workplan: saturation of cores with water, weak evacuation to eliminate air in the cores, measurement of water conductivity (k_W) (ref. 5), freezing with liquid nitrogen, freeze-drying, sealing the border of the samples (area between soil and cylinder), measurement of the air conductivity (k_L), saturation of the samples with gasoline, measurement of the gasoline conductivity (k_B), drying, careful saturation with water and once more measurement of the water conductivity (k_W^*). I eliminated values greater and smaller than $k_W/k_W^* = 2$ and 0,5 , calculated the permeabilities $k^o_{W,L,B}$ (ref. 6) and the zetapotentials (ref. 9). Hajnos measured the zetapotentials (ref. 4).

RESULTS

Flow is influenced by the charge of matrix and polarity and state of aggregation of a fluid (fig. 1). The calculated zetapotentials were 1500 mV, the measured ones were 10 to 60 mV and agree with data presented in the literature (ref. 1, 9 and 10).

DISCUSSION

The reduction in permeability for water vs. gasoline in soils with charge is due to adsorption and not to electroosmosis, because the low zetapotentials (as measure for an electrical potential difference, induced by water flow) do not allow an electroosmotic counterflow. The permeabilities, calculated for the cross-sections (F) of total samples for water and gasoline, have been related to the cross-section of the pores of the samples (k^{oo}). At gradients of 0,3 kPa/cm the relation $100\ F_W/F_B = 100\ r_W^2/r_B^2 = 100\ k_W^{oo}/k_B^{oo}$ was 100% for a Podsol-A_e, 25% for a Parabraunerde-B_t and 3% for a Pelogley-G_{or}. At gradients of 1,5 MPa/cm the relation (guessed from pore size distribution) should be at least 33% for a Parabraunerde-B_t and 27% for Pelogley-G_{or}. That means that k_W^{oo} (= $1/8\ r^2$, according to Hagen-Poiseuille) is proportional to the pressure gradient; so the law of Darcy is not valid. Dispersion or smearing out of a concentration front (ions or any other fluid component) depends not only on capillarity but also on diffusion of that concentration between mobile and immobile fluid fractions in a charged pore system.

TABLE 1

Soil data

Material	depth cm	pH ($CaCl_2$)	Cation exchange capacity Val/m^3	clay content %	density of soil kg/m^3	specific water volume at 0 Pa	specific water volume at 10 kPa	specific water volume at 1,5MPa
Podsol-A_e from sanstone	0-15	3,8	19	3[1)]	1170	0,56	0,13	0,02
Parabraunerde-B_t from silt-marl	70-90	5,2	293	33[2)]	1540	0,42	0,39	0,28
Pelogley-G_{or} from meadow-clay	75-105	4,5	346	50[2)]	1300	0,51	0,48	0,37

1) clay minerals: kaolinite, hydro-illite

2) clay minerals: illite, hydro-illite

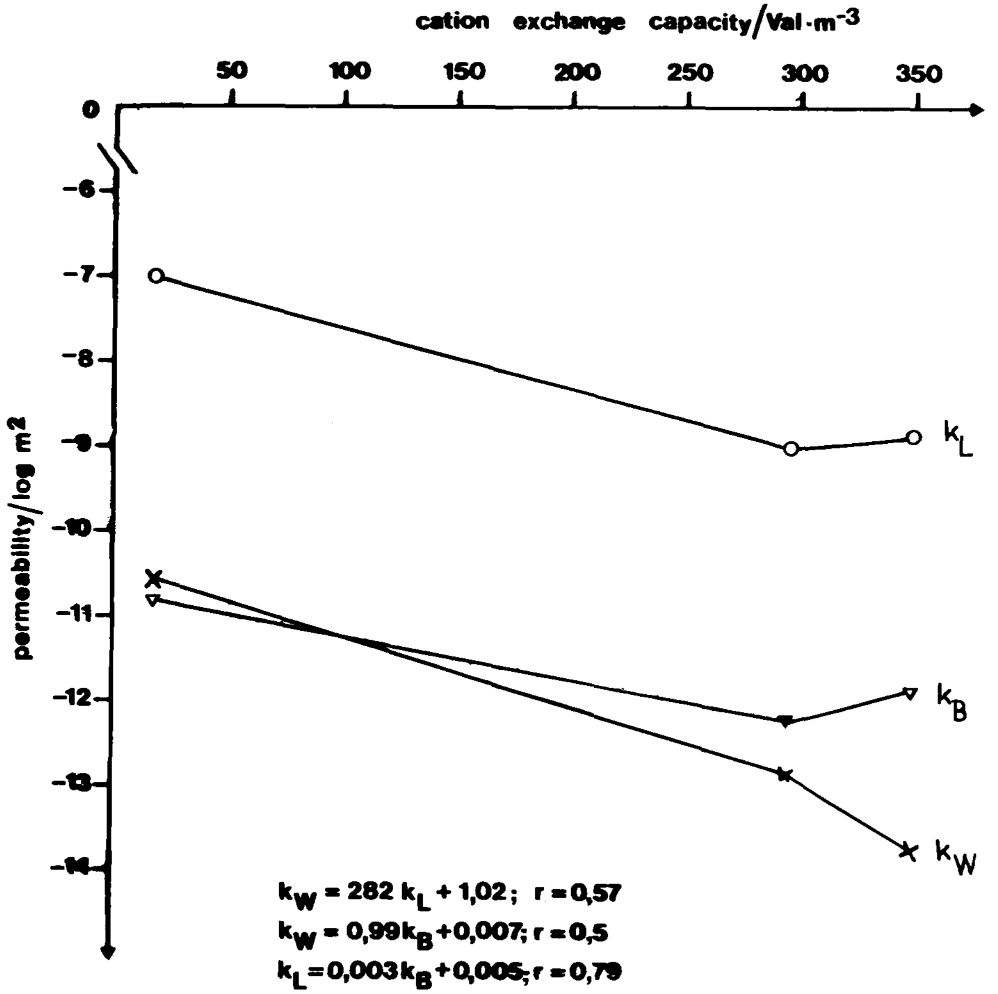

Fig. 1. Permeability k^{o} of air (L), gasoline (B) and water (W) versus cation exchange capacity.

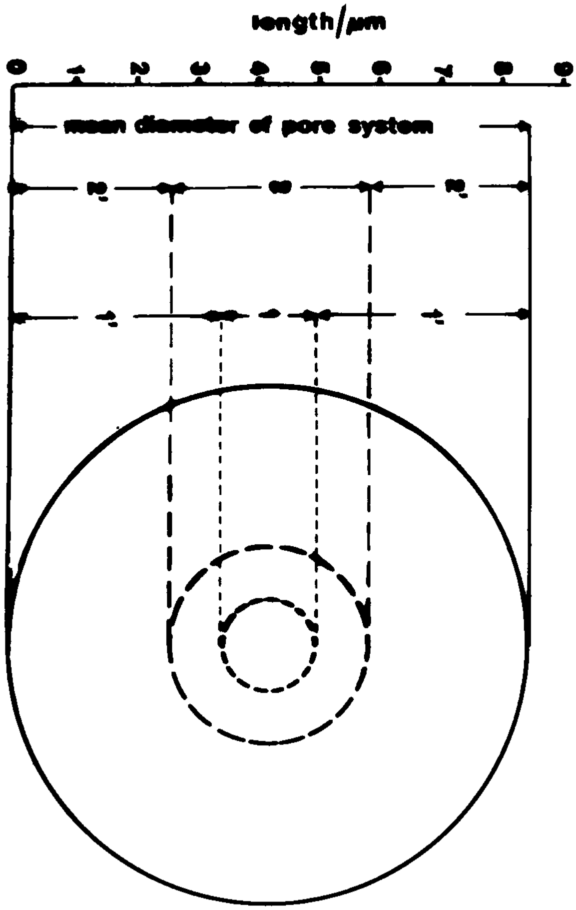

Fig. 2. The relation of sorbed to flowing water in a Pelogley-G_{or} at two pressure gradients.
1 = diameter of flow path at 0,3 kPa/cm,
2 = diameter of flow path at 1,5 MPa/cm,
1'= adsorbed water at 0,3 kPa/cm,
2'= adsorbed water at 1,5 MPa/cm.

REFERENCES

1 H. Billib und B. Hoffmann, Elektrokinetische Erscheinungen und ihre Bedeutung für die kulturtechnische Bodenkunde, Zeitschr. f. Kulturtechnik und Flurbereinigung, 6(1965)257-272.
2 P.C. Carman, Nature, 163(1949)684.
3 W. von Engelhardt und W.L.M. Tunn, Heidelberger Beiträge Min. Petrogr., 2(1954)12.
4 J. Glinski, M. Hajnos and J. Stawinski, The application of electro-osmosis in the determination of the electrokinetic potential in soil material, Polish J. Soil Sci., 6(1973)3-9.
5 K.H. Hartge, Die physikalische Untersuchung von Böden, Enke, Stuttgart, 1971.
6 K.H. Hartge, Einführung in die Bodenphysik, Enke, Stuttgart, 1978.
7 W.D. Kemper, Water and ion movement in thin filters as influenced by the electrostatic charge and diffuse layer of cations associated with clay mineral surfaces, Soil Sci. Soc. Am. Proc., 24(1960)10-16.
8 F. Low, Physical chemistry of clay-water interaction, Advances in Agronomy, American Society of Agronomy, Madison, Wisconsin, 13(1961)269-327.
9 E. Manegold, Kapillarsysteme, Band 2, Verlag Straßenbau, Chemie und Technik, 1960, pp.806-820.
10 J. Nissen und K.H. Hartge, Elektrische Potentiale im Zusammenhang mit Wasserbewegungen im Boden, Mitt. Dtsch. Bodenk. Gesellsch., 29(1979)171-176.
11 D. Swartzendruber, Non-Darcy behavior and the flow of water in unsaturated soils, Soil Sci. Soc. Am. Proc., 27(1963)491-494.