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# Hydraulic processes and properties of partly hydrophobic soils – capillary rise under transient wetting conditions

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## 1. The problem

Regular soil hydrology assumes hydraulic equilibrium. We state, that even for medium water repellent soils we also need to consider interfacial properties (wettability equilibrium in contact with water). This evidence is shown here with a simple experiment, where we wanted to show that:

- the capillary rise increases with time of contact with water. Time-dependent measurements show that, at defined height, the matric potential is always in **hydraulic equilibrium** with the height of the capillary rise. We state, that there is **no equilibrium in surface properties (Fig. 1)**,
- through changes in surface properties the soil capillary behaviour varies as well with time, indicated by long term increase of capillary height,
- The differences in matric potential between the pF curve obtained using ethanol (reference) and pF curves obtained for the samples which were in contact with water for different periods of time ($t_1$, $t_2$, $t_3$, …) are related to changes in surface properties and therefore **changes in contact angle** of soil.

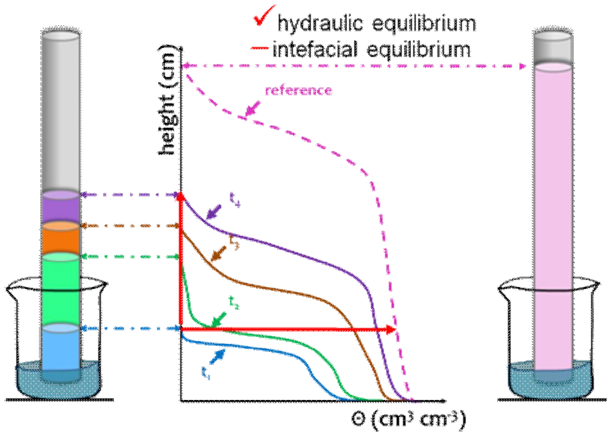


**Fig.1.** Schematic graph of changes in height of the capillary rise depending on the time ($t_1$, $t_2$, $t_3$, $t_4$) and water content; the potential maximum height of the capillary rise (reference) is shown as a scatter line

## 2. Study area

The studies were conducted in Fuhrberg, which is situated around 30 km NE from Hannover at the Lakwiese forest site (Lfor). The soils were characterized by a sandy texture (mSfs according to German soil texture classification) and a contact angle between 0 and 90˚C (i.e. the soils were partly hydrophobic).

## 3. Materials and Methods

In order to determine hydraulic processes of partly hydrophobic material disturbed soil material was collected from the top 0-30 cm soil layer. After air-drying disturbed soil material was homogenized (i.e. ground and sieved to ø<2000 µm) and then dried at different temperatures (50, 60 and 90˚C) in order to obtain different degree of water repellency. Such material was then packed into PVC columns of 50 cm height and around 3 cm diameter in order to obtain a bulk density of ~1.6 g cm$^{-3}$. The filled PVC columns were then submerged in water so that the bottom 2 cm of the soil column was below the water table. To keep the water level constant the water was supplied from the Marriotte's bottle. To investigate temporal changes in capillary rise of water different soil columns were left in contact with water for different periods of time (varying from 5 to 5000 h). In addition, in order to investigate changes in matric potential over time, we installed tensiometers in three columns at different heights (4, 8, 12, 20 cm above water table).

After defined period of time the soil columns were cut horizontally and gravimetric water content was defined for every 2 cm of the soil columns. Apart from these experiments were evaluated a potential capillary rise (reference) for our soils using 96% ethanol.

## 4. First achievements

The results showed, that with increase of time of contact with water the height of the capillary rise increased (**Fig. 2**). The maximum height of the capillary rise was obtained after the longest contact of soil column with water. The height of the capillary rise obtained using water was significantly lower compared with the reference curve obtained using ethanol.

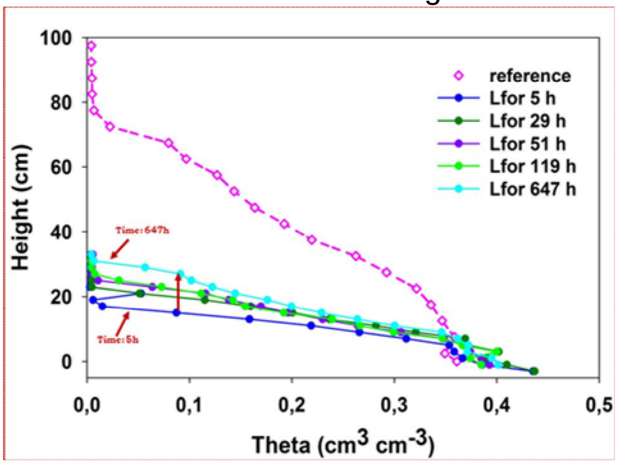


**Fig.2.** Changes in height of the capillary rise (cm) and water content ($cm^3$ $cm^{-3}$) of the samples taken from Lakwiese forest (Lfor) and dried to 50˚C. The numbers of hours indicate the time of contact with water.

Furthermore, the pF curves showed that (at defined height (pressure)) the water content increased with time due to changes in surface properties (**Fig. 3**). Moreover, the modeled pF curve (for 0.5 h) did not reflect the real, measured pF curves.

It could be also seen, that the matric potential at defined height (8 cm) remained remarkably stable while the water content at the same height (7 and 9 cm) increased with time (**Fig. 4**) which indicated that at defined height the matric potential was in hydraulic equilibrium with the height of the water table but the surface properties and the contact angle changed.

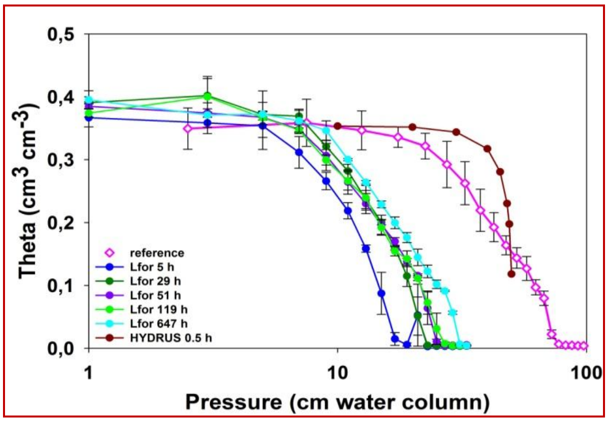


**Fig.3.** pF curves of the samples taken from Lakwiese forest (Lfor) and dried to 50˚C. The numbers of hours indicate the time of contact with water. The red curve indicates the simulated values using HYDRUS-1D based on the reference curve.

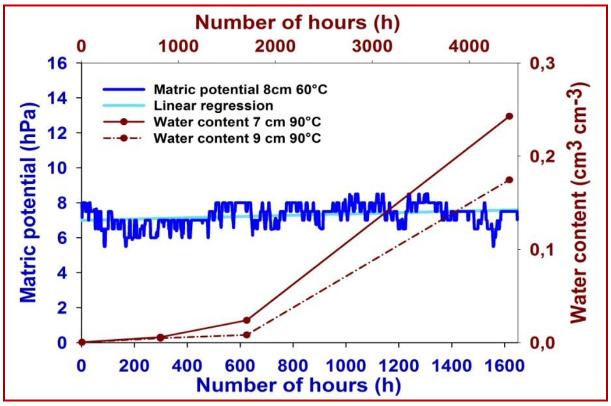


**Fig.4.** Time-dependent matric potential (hPa, blue) and water content ($cm^3$ $cm^{-3}$, red) determined for the samples taken from the Lakwiese forest and dried to 60˚C (matric potential curve) and 90˚C (water content curves). The matric potential and water content were determined for the 7-9 cm height.

## 5. Conclusions

In our investigations we could prove that:

1. the surface properties of partly hydrophobic soils vary significantly with time and, therefore, the contact angle also varies with time,
2. despite of local hydraulic equilibrium, in partly hydrophobic soils the capillary rise increases with time (time scale of weeks),
3. common hydraulic simulation does not consider time-dependent changes in surface wettability.