Neutron radiography measurements of drying front morphology in sandy media under different evaporation rates

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1. Introduction
- Drying of porous media is controlled by external conditions as well as by media transport properties that vary with phase distribution and pore space geometry.
- Key aspects of evaporative drying remain poorly understood. For example, experimentally determined drying rate are often enhanced compared to the one expected by vapor transport from drying front to the surface.
- We used neutron transmission technique to quantify both drying front dynamics and water content distribution within coarse sand.

2. Neutron radiography
- Glass Hele-Shaw cells (250 mm in height, 73 mm in width and 10 mm thickness) were packed with water saturated sand with particle size in the range of 300 to 900 μm.
- The attenuation of the neutrons was measured every 5 minutes.
- Upper boundary condition for evaporation was controlled using a hair dryer.
- Changes in total mass loss of column were recorded with a digital balance.

3. Drying rate
- Two evaporation experiments with different upper boundary conditions were conducted resulting in two different drying regimes.

4. Data analyses
- The transmission images contained values between 0 and 216 -1 with spatial resolution of 94 μm.
- To relate macroscopic mass loss with drying front geometry, the gray level image was segmented into a black and white image.

5. Front morphology
- The dynamics and geometry of the drying front (top, bottom and width of drying front) were not affected by drying rate.
- The front width is affected by pore-size distribution affecting pinning of the front in smaller pores.

6. The effect of hydraulic conductivity
- Higher hydraulic conductivity than measured drying rate indicated no constraints to mass flow.

7. Drying rate supplied by diffusion
- Diffusion of vapor from drying front to the surface can not explain measured drying rates.

8. Spatial water content distribution
- Fast air flow for the high potential rate may have resulted in lowering of surface water content at top 2 mm due to intensive turbulent mixing.
- Water content distribution below the surface was the same for high and low potential rates (no effect of boundary condition).

9. Enhanced drying rate
- Velocity and concentration boundary layer form near surface whose thicknesses vary with air flow velocity and humidity, respectively.
- Evaporation flux density can be given by:
  \[ e(x, t) = k(x) (C(x, t) - C_0) \]
  where C and k are the vapor concentration and local mass transfer coefficient, respectively.
- Higher velocity causing higher k, then higher drying rate.
- Reducing of surface water content resulting in decreasing of C with respect to time, then observing decreasing drying rate.

10. Summary and conclusion
- Water content distribution in space and time could be delineated with neutron transmission technique.
- The water content distribution is not affected by external boundary condition (evaporation rate).
- Dynamics and geometry of the drying front do not depend on drying rate.
- Diffusion fluxes and hydraulic conductivity cannot explain measured rates.
- Evaporation rate depends on upper boundary condition and on surface structure.