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Evaluation of LNAPL Migration under Fluctuating Groundwater by Image Analysis

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Light non-aqueous phase liquids (LNAPLs), such as petroleum products, can pose significant contamination risks to the groundwater when released in the vadose zone. Efficient and cost-effective remediation of these releases should be guided by field data, which, in turn, should be interpreted by numerical models using the appropriate assumptions.

Modeling of multiphase flow requires that the constitutive relations between relative permeability (k), saturation (S) and pore pressure (p) of the fluids are known in order to solve the governing flow equations.

Of these three variables, saturation has proved to be the most elusive to deal with when working in dynamic environments, and modern non-intrusive non-destructive methods, such as gamma ray or conventional X-ray attenuation techniques, while expensive, do not allow the acquisition of dynamic fluid saturation distribution in entire domains at one time.

Image Analysis

In this study, the accuracy of an image analysis method to assess the saturation of different soil samples was tested via a series of gravimetric experiments. The samples were photographed with a consumer grade digital camera (Nikon D70s), and the pictures were analyzed with a commercial technical computer software (MATLAB R2006a). The data (Fig. 1) showed a logarithmic relation (Eq. (1)) between saturation (S) and average optical density (D^{w}_{500}) for a particular optical spectral band (λ = 500 nm)

$$D^{w}_{500} = 0.0397 \ln S_w + 0.3293 \qquad R^2 = 0.9233 \tag{1}$$

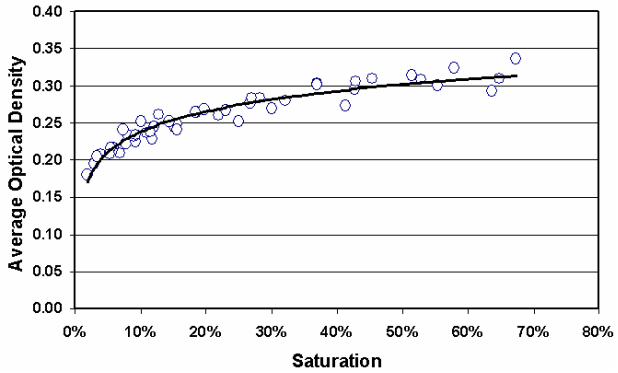

Fig. 1 Water saturation vs. average optical density

One-Dimensional Column

A 3.5×3.5×50 cm one-dimensional column with a glass-wall was designed in order to study, with the help of the image analysis method tested previously, the behavior of a lowering groundwater table in a Toyoura sand column (Fig. 2). Results showed good correspondence with measured saturation values.

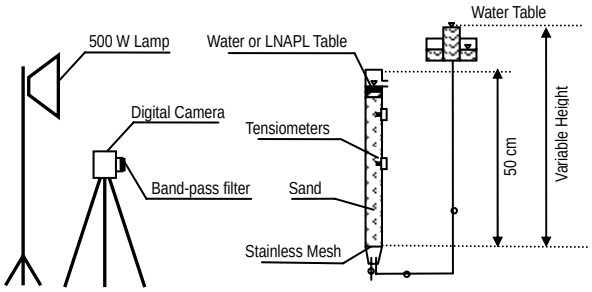

Fig. 2 One-dimensional column experiment design

k-S-p Relation Parameters

The use of the image analysis method tested here coupled with hydrophilic and hydrophilic tensiometers, proved a reliable yet economic method to obtain the van Genuchten parameters (α, n, S_{wr} and S_{nr}) used in most numerical models for NAPL migration in subsurface.