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Unstable Fingering Flow Visualization and Quantification Using Light Transmission Method

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With the aim of studying the physical process concerning the unstable fingering phenomena in two dimensions, experiments of vertical infiltration through layered sand were carried out in the laboratory using Hele-Shaw cells. We developed a light transmission method to measure the dynamics of water saturation within flow fingers in great detail with high spatial and temporal resolution. The method was calibrated using X-ray absorption. We improved the measured light transmission with correction for scattering effects through deconvolution with a point spread function, which allows us to obtain quantitative high spatial resolution measurements. After fingers had fully developed, we added a dye tracer in order to distinguish mobile and immobile water fractions. Fully developed fingers consist of a tip, a core with mobile water, and a hull with immobile water. We analyzed the dynamics of water saturation within the finger tip, along the finger core behind the tip, and within the fringe of the fingers during radial growth. Our results confirm previous findings of saturation overshoot in the finger tips and revealed a saturation minimum behind the tip as a new feature. The finger development was characterized by a gradual increase in water content within the core of the finger behind this minimum and a gradual widening of the fingers to a quasistable state which evolves at time scales that are orders of magnitude longer than those of fingers' evolution. In this state, a sharp separation into a core with fast convective flow and a fringe with exceedingly slow flow was detected. All observed phenomena, with the exception of saturation overshoot, could be consistently explained based on the hysteretic behavior of the soil-water characteristic.