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The Soil Foam Drainage Equation – an alternative model for unsaturated flow in porous media

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The analogy between the geometry and dynamics of wet foam drainage and gravity drainage of unsaturated porous media expands modeling capabilities for capillary flows and supplements the standard Richards equation representation. The governing equation for draining foam (or a soil variant termed the soil foam drainage equation – SFDE) obviates the need for macroscopic unsaturated hydraulic conductivity function by an explicit account of diminishing flow pathway sizes as the medium gradually drains. Potential advantages of the proposed drainage foam formalism include direct description of transient flow without requiring constitutive functions; evolution of capillary cross sections that provides consistent description of self-regulating internal fluxes (e.g., towards field capacity); and a more intuitive geometrical picture of capillary flow across textural boundaries. We will present new and simple analytical expressions for drainage rates and volumes from unsaturated porous media subjected to different boundary conditions that are in good agreement with the numerical solution of the SFDE and experimental results. The foam drainage methodology expands the range of tools available for describing and quantifying unsaturated flows and provides geometrically tractable links between evolution of liquid configuration and flow dynamics in unsaturated porous media. The resulting geometrical representation of capillary drainage could improve understanding of colloid and pathogen transport. The explicit geometrical interpretation of flow pathways underlying the hydraulic functions used by the Richards equation offers new insights that benefit both approaches.