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Boundary-trapped, inhalant siphon and drain flows: Pipe entry revisited numerically

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Abstract

Flows produced in suspension feeding and tube and burrow ventilation cause and influence many exchange processes and chemical reactions. I investigated two geometries, a capillary drawing water far from any other boundary and a constant-diameter drain flush with the bottom. Flow descriptions just inside these inlets have relied on solutions to pipe entry that posit uniform entrance velocity. I substituted the more realistic boundary condition of constant volumetric outflow rate in finite-element models for $0.01 \leqslant Re \leqslant 2000$. *Re* is the pipe Reynolds number, the product of mean capillary flow speed and capillary inside diameter (*D*) divided by kinematic viscosity of the fluid. For the smallest *Re* in both geometries, axial velocity reached 99% of its maximal value at a distance 0.2725*D* into the entry—not the 0.619 *D* found with uniform entrance velocity—and flow entering the capillary originated from a small, cylindrical region centered on the pipe axis. Axial flow velocities approaching the inlets therefore decreased away from the opening more slowly than predicted by simple convergence. For *Re* >330, flow converging on the capillary found traction on its outer wall (an apparent Coandă effect), and flow separation had major effects inside. Flow entering the siphon at these high *Re* values originated below the capillary entrance, and subsequent decrease in *Re* failed to dislodge the flow from its boundary-trapped state. Such hysteresis and flow bifurcation is unusual at low Reynolds numbers and could affect suspension feeders that deploy siphons and water samplers that use suction.

Keywords:hydraulic entrance length siphon flows pipe entry inhalant siphon bifurcation Coandă effect

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