

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 $0.01 \leq Re \leq 2000$. 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 $0.2725D$ 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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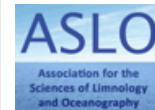
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