# Imaging Particle Swarms in Fractures with Miscible and Immiscible Fluids

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**ABSTRACT:** Immiscible fluids occur either naturally (e.g. oil & water) or from anthropogenic processes (e.g. liquid CO2 & water) in the subsurface and complicate the transport of natural or engineered micro- or nano-scale particles. In this study, we examined, experimentally, the effect of immiscible fluids on the formation and evolution of particle swarms in a fracture. A particle swarm is a collection of colloidal-size particles in a dilute suspension that exhibits cohesive behavior. Swarms fall under gravity with a velocity that is greater than the settling velocity of a single particle. Thus a particle swarm of colloidal contaminants can potentially travel farther and faster in a fracture than expected for an emulsion of colloidal particles.

Swarms were spherical, remained coherent and decreased in speed until as they came to rest on the oil-water interface. After the interface between a swarm and the oil thinned sufficiently, the swarm was rapidly released into the water. The swarm geometry and velocity in the water layer depended on the aperture of the fracture, the oil viscosity and the hydrophobicity or hydrophyllicity of the particles in the swarm. Hydrophobic beads result in multiple mini swarms after breaking through the interface rather than a single large swarm like that observed for hydrophilic swarms.

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