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Synthesis and characterization of environmentally friendly fluorescent particle tracers

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Tracers are widely used in experimental fluid mechanics and hydrology to investigate complex flows and water cycle processes. Commonly used tracers include dyes, artificial tracers, naturally occurring isotopes and chemicals, microorganisms, and DNA-based systems.
Tracers should be characterized by low detection limits and high accuracy in following water paths and flow structures. For natural studies, tracers are also expected to be nontoxic and with low sorption affinity to natural substrates to minimize losses in the environment. In this context, while isotopes are completely natural, their use in field studies is limited by their ubiquity and, therefore, by the high uncertainty in data processing methodologies. Further, the use of dyes and artificial tracers can be hampered by extremely low detection limits due to dilution in natural streams and microorganisms, while DNA-based system may require physical sampling and time-consuming functionalization and detection procedures.
In this work, we present the synthesis and characterization of fluorescent beads incorporating an eco-compatible fluorophore for environmental and laboratory applications. The particles are synthesized from natural beeswax through an inexpensive thermal procedure and can be engineered to present variable densities and diameters. A thorough characterization of their surface morphology at the nanoscale, crystal structure and size, chemical composition, and dye incorporation into the beeswax matrix is described by using a wide array of microscopy techniques. In addition, the particle fluorescence response is studied by performing excitation and emission scans on melted beeswax bead samples. The feasibility of using the synthesized particles in environmental settings is assessed through the design of ad-hoc weathering agent experiments where the beads are exposed to high energy radiation and hot water. Further, a proof of concept test is described to understand the particles' potential as a reliable hydrological tracer. In particular, an outdoor setup is developed where 250-420 μm environmentally friendly beads are deployed in high velocity flows. The transit of the beads is acquired with a miniature video acquisition system and images are analyzed to detect the particle transit.