Effects of particle geometries on dispersion in freestream turbulence

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The accumulation of plastic debris on ocean floors is an escalating environmental concern. The combined action of hydrodynamic forcing and ultraviolet-induced photodegradation promotes the fragmentation of plastic waste into smaller, irregularly shaped particles that can be transported over long distances before settling. Motivated by this process, we conducted an experimental study to investigate the settling and dispersion dynamics of negatively buoyant particles of varying shapes and sizes in turbulent open-channel flow. Experiments were performed in a recirculating water channel facility at the Norwegian University of Science and Technology (NTNU), featuring an 11 m-long and 1.8 m-wide test section with a water depth of 0.53 m. Freestream turbulence was generated by an active grid added at the test section inlet. Four flow conditions were considered, with freestream velocities of 0.25 m/s and 0.38 m/s, and turbulence intensities of 4% and 9%. Particles with four geometries, namely spheres, circular cylinders, square cylinders, and flat cuboids, were fabricated via 3D printing in two characteristic sizes (6 mm and 9 mm) using Tough 1500 resin. Each particle was released individually 30 mm below the free surface at a height of $h = 500$ mm. A catch grid was placed along the bottom channel wall to mark the particle landing location. For each flow condition, 200 drops were recorded for each particle shape and size. Results show that the mean streamwise advection distance of the particles is largely insensitive to turbulence intensity across all flow conditions. This suggests that the average settling velocity in this regime, estimated from linear advection using the particle settling velocity in quiescent flow, is only weakly affected by turbulent fluctuations. In contrast, particle dispersion, quantified by the root-mean-square of the landing locations, exhibits a strong dependence on particle geometry, size, and flow conditions. For all particle shapes, dispersion increases with freestream velocity and turbulence intensity, reflecting enhanced interaction with turbulent motions. An empirical scaling is proposed that relates streamwise dispersion to turbulence intensity, integral length scales, and particle settling velocity. These findings demonstrate that finite-size inertial particles do not disperse as passive tracers, and highlight the necessity of explicitly accounting for particle geometry in predictive models of particulate transport in aquatic environments (see Benonisen, Hearst and Tee, 2025).

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