Environmental transport of gyrotactic microorganisms in an open-channel flow

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The rich and complex phenomena of transport of motile microorganisms in shear flows, attracting intense research interest in recent years, are of great signiﬁcance to various biological and environmental applications. Recent studies have shown the properties of algae, e.g. swimming and gyrotaxis (a combined effect of gravitaxis and the rotation by shear flow), could have great influences on the active dispersion process. However, little attention has been paid to the initial and transient transport regime when the Taylor dispersion model is not applicable. We thus resort to Gill’s generalized dispersion model, which is also a classic analytical tool for the transport problem of passive particles. With a key extension of Gill’s model to the active transport problem for the first time, the effects of swimming, gyrotaxis and shear flow on the transient dispersion process in an open-channel flow have been thoroughly investigated. We first solve the temporal dispersion characteristics such as drift and the effective dispersion coefficient, then the evolution of both the vertical-mean concentration distribution and the two-dimensional distribution over the longitudinal and vertical directions are demonstrated. When there is no flow, we find that the dispersion process can be weakened by the accumulation of particles at the vicinity of water surface due to the gravitaxis, while it is enhanced by the random swimming of microorganisms. An imposed flow can induce a non-zero drift and greatly strengthen the dispersivity.