Realistic estimates of floc porosity based on high resolution 3D X-Ray microtomography

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Suspended particulate matter (SPM) plays a fundamental role in the impact and eventual fate of sediment, pollutants, pathogens, nutrients and manufactured nano-materials in aquatic environments. SPM usually exists in aquatic systems as flocs; complex, fragile and loosely-bound aggregates of fine sediment particles, bacteria, organic matter and fluid-filled pore space. Floc settling velocity is widely considered to be the most important dynamic characteristic that determines SPM fate and transport, and is dependent on the size, shape, density, porosity, fractal dimension and composition of the flocs formed in suspension. Of these characteristics, floc density and porosity are thought to exert the greatest impact on settling velocity, yet neither parameter can currently be measured. As such, transport model parameters are typically estimated from Stokes’ Law, based on an assumption of a spherical shape for the floc. Due to a lack of available observational data, such assumptions cannot be validated and porosity is often omitted with flocs treated as essentially impermeable spherical entities, despite pores accounting for much of the defined ‘floc-space’ (often estimated to be > 90% within larger macro-flocs).

As part of a wider project exploring the 3D nature of floc structure and dynamics (NERC-3D Flocs), this study reports a first application of high-resolution 3D X-Ray microtomography on populations of flocs, offering a method that quantifies 3D floc porosity based on observation rather than assumption of floc structural properties. High resolution (3 µm voxel size) scans of both laboratory-generated and natural floc populations, from which sub-populations of different-sized micro- and macro-flocs (30 in each of 5 size categories for each floc population) are extracted. A data-processing workflow is presented which applies 3D morphological filters to systematically define a realistic expression of the total pore-space associated with individual flocs. Floc pore-space is further partitioned into isolated and effective pores, based on a 12 µm pore throat diameter threshold below which fluid flow is hydrodynamically minimal. Analysis of these realistic floc porosity data populations indicates that previous assumptions of floc porosity lack meaning in
terms of settling dynamics. Substitution with meaningful, realistic floc porosity will have a significant impact on the prediction of floc settling velocity within SPM sediment transport models.