Modelling of mixing processes in water treatment using computational fluid dynamics (CFD)

The role of mixing in floc formation and breakage

Effective coagulation and flocculation processes are fundamental to the efficient operation of surface water treatment works. Coagulation brings about a change in the nature of small particles, rendering them unstable, whilst flocculation encourages particle agglomeration via gentle mixing. Ineffective coagulation and flocculation results in poorer quality feed water to clarifiers and filters, potentially jeopardising treated water quality and increasing operational costs. Several interrelated criteria govern the efficiency and effectiveness of the coagulation and flocculation stages; viz. coagulant dosage (including coagulant type), pH and mixing arrangements.

Flocs are irregularly-shaped, loosely connected aggregates which are formed via the destabilisation and subsequent agitation of smaller primary particles. The strength of these flocs is of great importance for particle removal efficiency with particle removal efficiency decreasing with decreasing particle size. Therefore, flocs must be able to withstand shear energy applied to them in various different unit processes. When the degree of shear exceeds a threshold value, floc breakage will occur. This breakage has, for certain flocs, been shown to be irreversible and measurement of the shear energy required for breakage is of major operational significance. However, quantification of the energy requirements for floc breakage is not straightforward, and despite much work in this field, no standard strength test exists.

The literature shows many examples of floc breakage characteristics obtained from the standard jar test. However, breakage and the shear forces imparted to yield breakage are usually expressed in terms of the impeller mixing speed. Clearly, this is of limited value if one wishes to understand the impact of the induced hydrodynamic environment on flocs in a full scale flocculator. The clear differences in mixing scenarios mean that it is not possible to transfer results from one scale to another. This project seeks to overcome this difficulty by investigating the practicalities and effectiveness of using computational fluid dynamics (CFD) to assess flocculator characteristics, to align the measured hydrodynamic environment with known floc behaviour (growth / breakage) patterns, from which parameters for effective flocculation design and operation can be developed. Key parameters governing effective flocculation can be elucidated and quantified, enabling process scientists and engineers to develop effective design criteria and operational strategies.

This project is focussed on physical and numerical analyses of laboratory and full scale flocculators. The laboratory scale work examined two different jar test configurations, whilst the full-scale study considered the operation of large hydraulic and mechanical flocculators. The project uses CFD to investigate the nature of mixing at each of the two scales and possible links between hydraulic characteristics of the flow (such as velocity gradient and turbulence) and floc formation and breakage. A number of CFD techniques have been adopted depending on the process configuration being modelled:

- Steady and unsteady flow
- Conventional single-phase hydraulic modelling
- Two-phase modelling where a dispersed second phase is mixed with the bulk phase
- Residence time distributions.