# Tracing Particle Movement for Simulation of Light History and Algal Growth in Airlift Photobioreactors using Positron Emission Particle Tracking (PEPT)

-Abstract for PhD thesis – M. Brighton 2017

Microalgae show potential for the production of bioenergy products and bulk feeds, or lipids and other specialty chemicals, with greater efficiency and versatility than terrestrial crops. Previous work has investigated species, mixing and nutrient requirements, and the average light experienced by the culture. This study focuses on the 'light history' of individual cells as they circulate the photobioreactor, as greater understanding may result in higher efficiency.

Algal cell movement around a draft-tube Airlift Reactor (ALR) was determined through Positron Emission Particle Tracking (PEPT) using novel tracers containing a $\beta^+$ emitting radioisotope (Gallium-68) in a small, neutrally buoyant particle. This was traced as it moved around a functioning ALR containing either water or a growing microalgae culture to an accuracy of ±2 mm at >30 Hz in the PEPT-UCT PET scanner (Buffler et al., 2009). Extensive amounts of data for a number of ALR configurations and injected gas flowrates were obtained, allowing extensive characterisation of tracer movement, indicative of both fluid and algal cell movement. Single metrics, such as circulation times and distances, were determined and characterisations such as occurrence, velocity or Reynold's number per voxel were calculated. The time and movement in each section of the ALR were determined, giving insights into the effect of ALR design and gas flowrate. Analysis showed the expected increase in circulation time with decreasing injected gas flowrate, although there was only a small change in the time spent in the central riser. Particles in the downcomer, where the majority of light is absorbed, showed small radial movement once out of the turbulent, swirling pattern at the top. However, this does not support published assumptions of streamline flow in the downcomer, as there were still enough changes in distance to the outer wall to result in significant variation in light intensity, particularly at higher light intensities or higher algal concentrations.

The PEPT trajectories provided an accurate radial position, determining how far the tracer was from the outer wall of the ALR, assumed to be the light source. This was converted into a light history using the dual-asymptotic light attenuation model of Suh & Lee (2003), which was the input for an Algae Growth Simulation (AGS) developed with the Photosynthetic Factories model of Eilers & Peeters (1988) as a basis. Empirically determined constants in both models were taken from earlier work on *Scenedesmus* by Fraser (2011) or *Porphyridium* by Wu & Merchuk (2002). The constants were developed from growth with adequate provision of all nutrients ($CO_2$, N, etc.), thus the only limitation was light. Based on the PEPT-derived light history, the results from the novel AGS found that, below a critical gas flowrate, there was a drop in algal growth (below 0.004 m/s or 0.008 m/s superficial gas velocity in an 84 mm or 100 mm diameter ALR respectively). This effect was only due to mixing patterns and lower frequency light/dark cycling at the lower gas flowrates.

This study has shown that PEPT has been developed as an effective tool for studying photobioreactors. Flow patterns in the airlift reactor can be shown and a descriptive light history determined. This can be integrated to provide insights into the light which individual algal cells experience and the effect on overall growth.

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