Summary

The thesis focuses on synthesis and characterisation of self-immobilised phototrophic biofilms (in the form of aerobic microbial granules) and their application in waste degradation. Aerobic granulation has been very actively researched in the recent past, with emphasis ranging from microbial diversity to process optimisation. But most of the work has been done by using synthetic wastewater; more studies are required to address granulation in industrial wastewaters and to achieve short start-up times.

The work resulted in optimisation of a simple reactor system for laboratory level cultivation of aerobic microbial granules. The shake flask based reactors can be easily operated and are ideal for carrying out multi-parametric parallel studies. The study further examined the use of alternate seed source (e.g. biofilms) to grow granular sludge in order to reduce the start-up time of the reactors. Erlenmeyer flasks were used as microreactors for providing the conditions required for biogranulation. The development of granules in shake flask reactors was accomplished using two types of industrial wastewaters and synthetic wastewater. The size of granule was a function of organic strength of the wastewater. DO was found to behave like surrogate parameter for COD during a given SBR cycle in the passively aerated reactor system. The microbial diversity of granules was very dynamic and changed with time as well as with the type of wastewater.

The shake flask reactors were used for optimization of shear (in the form of rotational speed) required for granulation and also for development of granules from alternate source of seed biomass (substratum-bound biofilms) with the objective of reduction in start-up time. Further, the effect of quorum sensing molecules (acyl homoserinelactone) on granulation was also studied. Minimum of 100 rpm rotational frequency was required for granulation. The size of granules was an inverse function of shaking frequency, while settling velocity was a direct function of the shaking frequency. The sludge in 150 rpm reactor was comparable to the sludge formed in a bubbled column SBR operated at 1 cms⁻¹ upflow air velocity. Aerobic granules could be developed from the biomass enriched from biofilms formed in a freshwater body, which
reduced the start-up time. Granulation was observed after one week of reactor operation and sludge became fully granular in less than two weeks. Addition of quorum sensing molecule improved the granulation and reduced growth of filamentous microbes.

Aerobic granulation process has two major limitations. First, they need input of costly organic carbon and second, they have limited metabolic and microbial diversity. Both these limitation can be overcome if phototrophic microbes (cyanobacteria and microalgae) could be incorporated into aerobic granules. Additionally, phototrophic biofilms have huge potential in environmental biotechnology (e.g. PHOBIA project of EU http://www.photobiofilms.org, accessed 01.09.2011). However, large scale application of phototrophic biofilms suffers from the drawback of requirement of large area for solar illumination.

The work on aerobic granulation was continued with the objective of convergence of these two (aerobic granulation and phototrophic biofilms) types of biotechnologically important biomass and to generate a novel biomass, which can overcome the drawbacks of both the technologies and provide a metabolically more diverse and potent tool in environmental biotechnology. Self-sustaining phototrophic granular biomass was successfully cultivated using different approaches in shake flask as well as bubble column photobioreactors from biomass seed ranging from pure cultures to mixed consortia like activated sludge and mix of algae derived from substratum-bound biofilm.

The SSPGs were then used for demonstrating their usefulness in degradation of a sample pollutant (phenol), without input of any additional carbon sources. The experiments demonstrated the robustness of the system in terms of granule integrity and xenobiotic degradation. Phenol was degraded at the rate of 30.9 mg.g\(^{-1}\).h\(^{-1}\) (calculated per unit dry biomass). Sufficient availability of light was found to be crucial for the efficient biodegradation of phenol. Low light availability at high phenol loading rate (2.1 kg m\(^{-3}\) d\(^{-1}\) in 8 h SBR cycles) resulted in loss of function. However, the loss could be reversed and functionality was recovered to its original level after temporarily withdrawing the phenol addition and increasing the light availability.