Synopsis

The scarcity of water and strict environmental regulations have made sustainable engineering a prime concern in the process and manufacturing industries. Water minimisation involves the reduction of freshwater use and effluent discharge in chemical plants. This is achieved through water reuse, water recycle and water regeneration. Optimisation of the water network (WN) superstructure considers all possible interconnections between water sources, water sinks and regenerator units (membrane systems). In most published works, membrane systems have been represented using the “black-box” approach, which uses a simplified linear model to represent the membrane systems. This approach does not give an accurate representation of the energy consumption and associated costs of the membrane systems.

The work presented in this dissertation therefore looks at the incorporation of a detailed reverse osmosis network (RON) superstructure within a water network superstructure in order to simultaneously minimise water, energy, operating and capital costs. The WN consists of water sources, water sinks and reverse osmosis (RO) units for the partial treatment of the contaminated water. An overall mixed-integer nonlinear programming (MINLP) framework is developed, that simultaneously evaluates both water recycle/reuse and regeneration reuse/recycle opportunities. The solution obtained from optimisation provides the optimal connections between various units in the network arrangement, size and number of RO units, booster pumps as well as energy recovery turbines. The work looks at four cases in order to highlight the importance of including a detailed regeneration network within the water network instead of the traditional “black-box’’ model. The importance of using a variable removal ratio in the model is also highlighted by applying the work to a literature case study, which leads to a 28% reduction in freshwater consumption and 80% reduction in wastewater generation.