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A process integration technique for integrated water and regeneration networks that are characterized by variable removal ratios

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Synopsis

Water management has become a very critical issue for process and manufacturing industries due to the escalating costs of freshwater and wastewater treatment. These costs arise from the rapid depletion of this natural resource and this has heightened the need for sustainable engineering within industry. The aim is to ensure that operations adhere to the stringent environmental regulations placed on wastewater discharge while optimizing on production. As a result, process integration is applied in industries for sustainable water management through exploiting opportunities of water reuse, recycle and regeneration. This can be achieved through optimization of the water network, which integrates the different water sources, sinks and regeneration units. However, upon the incorporation of a regenerator in the water network, the synthesis problem becomes very complex. As a result, water pinch analysis is integrated with mathematical modelling in this dissertation to help reduce both model complexity and convergence issues. To be attained from such a framework are conceptual insights of the water network from pinch analysis and rigorous designs from mathematical optimization. In literature, these techniques are used independently with pinch analysis limited to black-box representation of the regeneration network, which uses linear cost functions to account for wastewater treatment. However, detailed regenerator designs can be achieved with mathematical modelling, thereby capturing true regeneration cost.

The work presented in this dissertation, therefore, looks at the development of a systematic optimization framework that integrates graphical insights with mathematical modelling to reduce both model complexity and computational time. The graphical technique adopted in this work is Composite Table Algorithm (CTA), which is improved to determine an optimal regenerator removal ratio (RR) that simultaneously minimizes the freshwater requirement and wastewater generation within the water network. The improved CTA is demonstrated using literature examples for both fixed load and fixed flowrate problems. It is further adapted to solve a multiple contaminant problem using the reference contaminant approach. The mathematical model developed includes a detailed design of a reverse osmosis (RO) unit to allow for simultaneous optimization of water and energy used by the regenerator. This provides accurate cost estimation of the water network rather than the linear cost functions associated with the use of black-box representations in graphical targeting. Upon integrating the graphical and mathematical techniques in this study, results show that there was a reduction of about

85% in CPU time. This implies that the model converges faster and therefore favours the use of insight-based techniques as a preprocessing step for mathematical modelling.