Abstract

The increase in the degradation of water sources and stringent environmental regulations have greatly motivated industries to explore means of utilizing water efficiently. Batch processes are known to generate highly contaminated wastewater that is toxic to the environment. A holistic approach to design which emphasizes the unity of the process, process integration (PI), can be used to reduce both the wastewater generated and the level of contamination while maintaining the profitability of the chemical plant. Process integration techniques for wastewater minimization in batch processes include water reuse, recycle and regeneration.

Most mathematical formulations for wastewater minimization in multipurpose batch processes presented in literature determine the amount of water required for washing operations by only looking at the task that has just occurred in a unit. However, the nature of the succeeding task can influence the amount of water required for the washing operation between consecutive tasks in a processing unit. In paint manufacturing, for example, more water will be required for the washing operation if the production of white paint follows the production of black paint and less water will be required if the black paint follows the white paint. The amount of wastewater generated in batch processes can, therefore, be reduced by simply synthesizing a sequence of tasks that will generate the least amount of wastewater. Presented in this work are wastewater minimization formulations for multipurpose batch processes which explore sequence dependent changeover opportunities for water minimization simultaneously with direct and indirect water reuse and recycle opportunities.

The presence of continuous and integer variables, as well as bilinear terms, rendered the model a Mixed Integer Nonlinear Program (MINLP). The developed MINLP model was validated using two single contaminant illustrative examples and a multiple contaminant example. A global optimization solver, Branch and Reduce Optimization Navigator (BARON), was used to solve the optimization problems on a General Algebraic Modeling System (GAMS) platform. Exploring multiple water saving opportunities simultaneously has proven to be computationally intensive but can result in significant water savings. For instance, two different scenarios saved 65% and 61% in freshwater use respectively.