frontiers | Frontiers in Chemical Engineering

TYPE Editorial
PUBLISHED 31 October 2022
DOI 10.3389/fceng.2022.1012754

OPEN ACCESS

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SPECIALTY SECTION
This article was submitted to Computational Methods in Chemical Engineering, a section of the journal Frontiers in Chemical Engineering

RECEIVED 05 August 2022
ACCEPTED 17 October 2022
PUBLISHED 31 October 2022

CITATION
Ahmetović E, Grossmann IE, Kravanja Z, Maréchal FMA, Klemeš JJ, Savulescu L and Dong H (2022), Editorial: Combined water and heat integration in the process industries.
Front. Chem. Eng. 4:1012754.
doi: 10.3389/fceng.2022.1012754

Editorial: Combined water and heat integration in the process industries

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KEYWORDS

water integration, heat integration, systematic methods, pinch analysis, mathematical programming, heat-integrated water networks, optimisation, process industry

Editorial on the Research Topic
Combined water and heat integration in the process industries

Water and energy are resources that are used in large quantities in different sectors (domestic, agricultural, and industrial). Based on data on global water and energy consumption in the world over the recent past, as well as forecasts for the coming years, a continuous trend of increasing water and energy consumption can be observed. The expected growth of the human population in the future and the needs for various products are some of the reasons for this trend. The industrial sector will play a very significant role in the future in providing a wide range of products for the market to satisfy the needs of the human population. As a consequence of the increased production, the consumption of natural resources (raw materials, energy, and water) will increase in the industrial sector. Some of the main challenges are discovering strategies and solutions for sustainable use of water, energy, and other natural resources in the industrial sector, especially in processes that are large consumers of these resources. This is very important in designing new processes, but also in the operation of existing processes. As a result, economic efficiency and environmental sustainability of processes in the industrial sector can be achieved.

Water and/or Energy/Heat Integration problems in the process industry have attracted the attention of many researchers over the last decades. Systematic methods based on Pinch Analysis (PA), Mathematical Programming (MP) or their combinations (PA-MP) have been applied for solving these problems, including also alternative optimisation tools (e.g. Process Graph (P-Graph)). The majority of works have been focused on solving the water integration problem or the heat integration problem in isolation from each other. Most recent works have applied MP primarily to address combined water and heat integration problems, including large-scale problems with single and multiple freshwater sources and single and multiple contaminants in water streams. This research field is also known in the literature as the synthesis of Heat-Integrated Water Networks (HIWNs), Heat-Integrated Water Allocation Networks (HIWANs), Non-Isothermal Water Networks (NIWNs), or Combined Energy and Water Networks (CEWNs). The opportunities for water conservation (wastewater reuse, wastewater regeneration reuse, and wastewater regeneration recycling) and heat exchanges (indirect and direct heat transfer) are systematically explored in these networks to find optimal network design solutions. For more information about this field, the reader is referred to papers that provide a review of recent progress and future PI directions (Klemeš, 2022), in the synthesis of HIWNs (Ahmetović et al., 2022), applications of systematic methods for HIWNs optimisation in specific processes, e.g. Kraft pulp mills (Ahmetović et al., 2021), a review of MP methods including sectorial case studies (Budak Duhbacı et al., 2021), solution strategies, and network features (Kermani et al., 2018), and a comprehensive review of works and methods based on PA, MP and their combinations (PA-MP) (Ahmetović et al., 2015).

There are three articles published as a Research Topic within this Research Topic. In the first paper, Caballero et al. presented a novel sequential approach for the design of HENs using the MP approach. The concepts of temperature intervals and superstructure were applied to new MILP-MINLP models. The proposed method used an adaptation of the TransHEN model in the first step, based on temperature intervals and a fixed Heat Recovery Approach Temperature (HRAT) to allow calculation of the logarithmic mean temperature difference and to maintain the area estimation linear. The HENDesign model, based on a superstructure, was solved in the second step for a set of matches obtained in the first step by allowing the re-optimisation of heat flows, temperature and heat exchange areas. These models were solved by using a sequential solution strategy and tested on fifteen benchmark HEN problems. The results presented in the manuscript are very promising and in good agreement with the literature results. The presented models and solution strategy can be considered, re-adapted, and combined with WN models to address the synthesis of HIWNs.

In the second paper, Oliveira et al. focused on the optimisation of water and energy networks. They considered a case study consisting of three water-using processes and different models (an MINLP model, a Multi-Objective Programming (MOP) model, and an integrated MINLP and NLP model) to solve this case study to minimise water and energy consumption and design a HIWN. The first two models (MINLP and MOP) considered only direct water recirculation as the method for heat recovery, while an additional NLP model was applied for further heat integration based on heat exchanger installation. The most favourable results were obtained by the integrated MINLP and NLP model when compared to the MOP model. The comparison of the obtained results was performed with the previously reported results for the considered case study. There is room for improvement of the proposed models and strategy used in this work, especially to address and solve large-scale HIWN problems with multiple contaminants in water streams.

In the third paper, Jakata and Majozi presented a superstructure-based optimisation approach and corresponding MINLP model for the synthesis of nanofiltration membrane regeneration networks and their application in water minimisation problems. The effect of combining the Spiegler-Kedem and the Steric Hindrance Pore Models was investigated to determine the optimal membrane and module properties, which are important in the design of nanofiltration networks. The proposed approach was applied to a case study of a pulp and paper plant, considering different scenarios with an increasing level of model complexity. The presented solutions demonstrated that economic and environmentally efficient benefits can be obtained by the proposed approach. The presented model can be extended to incorporate multiple types of regenerators and consider also heat integration.

We hope that this Research Topic and Research Topic of works will be useful for the readers as an overview and introduction to the topic, as well as a relevant showcase of the research works associated with this topic.

Author contributions

EA drafted the first version of this editorial. All authors contributed, revised, and approved the final version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

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