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Editorial

Editorial – Challenges and opportunities in advanced processes based on distillation for sustainable processes

Distillation is a fundamental chemical process in industry that separates components of a liquid mixture based on their unique physical and chemical properties. It is widely recognised that distillation is highly energy-intensive and has a significant environmental footprint. Consequently, addressing the challenges and exploring the opportunities in advanced distillation processes is crucial for achieving sustainable industrial practices. Advanced techniques like azeotropic and extractive distillation, which use additional separating agents, show promise in reducing energy use. Additionally, implementing heat recovery systems and optimising equipment design can further enhance energy efficiency. Waste and emission management is another critical issue, as distillation can produce harmful by-products. Adopting environmental management practices and advanced waste treatment technologies can mitigate these impacts.

This Special Issue (SI) features 23 articles from the authors in 8 different countries, with a significant contribution from China, i.e. 14 articles. The articles cover a wide range of distillation processes, from conventional methods to advanced techniques like pressure swing distillation, heterogeneous azeotropic distillation, and extractive distillation. To further promote energy savings, several studies have integrated process intensification components to enhance separation performance. Most of the studies in this SI are simulation-based. However, they go beyond steady-state simulations, with several also explore the dynamic simulation aspects (i.e., controllability). Finally, there are also some studies we categorised as special studies, which address specific contexts, countries, or unique applications.

In the context of conventional distillation, Kong et al. (2024) presented a comprehensive study on fluid catalytic cracking gasoline. They began by designing a conventional dual-column system and then extended their research to explore process intensification using side streams and dividing wall columns. The intensified dividing wall process showed significant cost and environmental advantages. Additionally, they examined the control performance of this intensified process, demonstrating that their control scheme can effectively handle disturbances of up to ± 20 % in feed flow rates. Caballero-Sanchez et al. (2024) proposed an aqueous two-phase system for recovering 1,4-butanediol from aqueous solutions using potassium carbonate as a phase-forming agent, eliminating the need for additional solvents. The aqueous two-phase systems was simulated in Aspen Plus and they successfully demonstrated that the potassium carbonate acts as an effective dehydrating agent for the recovery of 1,4-butanediol obtained by fermentation. Beyond conventional distillation systems, Gholami et al. (2024) conducted a comprehensive analysis of 18 different enhanced pressure swing distillation scenarios for separating water and acetonitrile. These scenarios included both process intensification and integration techniques aimed at addressing the inherent challenges of pressure swing distillation, such as high operating costs and energy consumption. Sun et al. (2024) focused on heterogeneous azeotropic mixtures, which is another advanced distillation process dedicated to separating azeotropic mixtures with heterogeneous properties. They also extended their study to include process intensification component, with an aim to promote energy savings.

Compared to pressure swing and heterogeneous azeotropic distillations, extractive distillation seems to attract more attention in this SI. Kang et al. (2023) investigated the separation of isopropanol, n-propanol, and water, commonly formed from the direct hydration of propylene to produce isopropanol, using extractive distillation. They compared the performance of ionic liquids against traditional organic solvents, demonstrating that ionic liquids significantly enhanced cost efficiency and reduced environmental impact. Yang et al. (2024) worked on separating isopropyl alcohol and isooctane from industrial wastewater using extractive distillation. In addition to traditional simulation with Aspen Plus, they explored molecular mechanisms, which include quantum chemical and electrostatic potential, for solvent selection. Wang et al. (2024) combined extractive distillation with pervaporation to separate cyclohexane and isopropyl alcohol from industrial effluent. Their hybrid process was compared to conventional extractive distillation, displaying lower costs and reduced environmental emissions.

In addition to the focus on advanced distillation processes like pressure swing distillation, heterogeneous azeotropic distillation, and extractive distillation, several studies aimed to improve separation performance and reduce energy consumption through process intensification. One example is the work of Wu et al. (2024), who introduced a preconcentration column to conventional extractive distillation for separating ethyl acetate and ethanol from wastewater. They further implemented a vapour recompression heat pump, revealing that the intensified process significantly improved cost, environmental, and energy performances. Feng et al. (2023) worked on a liquid-only side-stream distillation process, eliminating the vapour split in dividing wall columns whilst maintaining comparable economic and thermodynamic efficiency. Gotama et al. (2024) proposed a novel hybrid intensification process combining side stream and thermal coupling for diphenyl carbonate production. This hybrid process significantly improved energy consumption and cost compared to the conventional reactive distillation. They also explored the dynamic controllability of their proposed process, showcasing an effective control structure to handle feed and composition disturbances. Nhien et al. (2024) explored the production of electronic-grade propylene glycol monomethyl ether acetate using

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pressure swing distillation and various intensified techniques, such as dividing wall columns, reactive dividing wall columns, and side-reactor dividing wall columns. The side-reactor dividing wall column emerged as the most promising option, providing the largest energy and cost savings. Regmi et al. (2024) worked on membrane distillation integrated with crystallisation for sustainable produced water treatment. They focused on pre-treatment, examining a pilot-scale integrated electro-coagulation-microfiltration system. This efficient pre-treatment is crucial for stable performance, reducing fouling and wetting caused by high inorganic content and oil-grease presence. They achieved a 40 % reduction in total organic carbon, a 22-fold decrease in total suspended solids, and a 600-fold decrease in turbidity, enhancing suitability for subsequent membrane distillation. Another widely studied advanced distillation process is hybrid reactive-extractive distillation. Du et al. (2023) focused on this process for separating tetrahydrofuran, methanol, and water, performing multi-objective optimisation and multi-criteria decision making that considers economic, environmental, and safety factors. Liu et al. (2023) studied the hydrolysis of sec-butyl acetate to Sec-butyl alcohol, utilising a mixed solvent for downstream separation of Sec-butyl alcohol and water. They also explored process intensification techniques like thermal coupling to enhance their proposed process.

In addition to the studies that feature steady-state simulation, there are several that explore dynamic simulations (i.e., controllability). Li et al. (2023a) investigated the controllability of an extractive dividing wall column for separating a quaternary azeotropic mixture of acetone, methanol, butanone, and tert-butanol. They developed several control strategies, which include temperature control, temperature-difference control, and composition control, to maintain product purity despite disturbances in feed flow and composition. They demonstrated that the temperature-difference control could effectively maintain product purities in the extractive dividing wall column. Similarly, Geng et al. (2024) worked on controlling hybrid reactive pressure swing distillation for producing isopropanol *via* the transesterification of isopropyl acetate with methanol. A unique approach was presented by Udugama et al. (2024), who developed a novel process operations and control principle for flexible operation of a high-purity methanol distillation column in volatile energy markets. Their concept of using a distillation column as a "process battery" represents a significant departure from the traditional process control, which typically focuses on maintaining steady operations under all conditions. Li et al. (2023b) introduced a mechanism-data hybrid-driven framework to capture the delay time and dynamic response of process variables in an actual de-Ethanisation process. Their framework combines non-parametric identification methods, theoretical models, and big data analysis technology. This approach outperforms traditional identification methods, which often suffer from low accuracy and noise interference, making it crucial for accurate process analysis, prediction, and optimisation. Zhou et al. (2024) integrated dynamic simulation with the concept of protection layers to assess the dynamic safety of an extractive distillation operation. Addressing the separation of acetonitrile from water using ethylene glycol as a solvent, they evaluated the effectiveness of various independent protection layers, such as basic process control systems, critical alarms, operator interventions, safety instrumented systems, and pressure relief valves, against various potential risk scenarios.

Lastly, this SI is wrapped up with some rather special studies that cover specific countries or unique applications. Ye et al. (2023), for example, conducted a compelling investigation into the separation of the high global warming potential refrigerant R410A (a 50/50 blend of R32 and R125), which has significant industrial relevance. Their study compared the performance of traditional organic liquids with ionic liquids for this separation, revealing that organic liquids remain the superior choice over ionic liquids. Arenas-Grimaldo et al. (2024) took a unique approach by focusing on the purification of ethanol derived from Sotol bagasse, a by-product of traditional Sotol production in Mexico. Their work highlights an innovative solution for a specific regional by-product with the potential for increased efficiency in ethanol recovery. Anugraha et al. (2024) simulated the CO_2 separation process from high-concentration gas reservoirs in Indonesia, specifically using cryogenic distillation with Pellegrini and CFZ methods. They analysed both technologies for their energy demands, recovery rates, and purity, showing that CFZ technology offers a more economical option compared to Pellegrini's method.

Overall, the articles presented in this SI address a wide range of research problems on the advancement of distillation processes and their applications. The collection of studies reflect a concerted global effort in resolving the challenges of energy consumption, environmental impact, and process efficiency of the distillation processes. We hope that the insights gained from these studies will spark further exploration in the field. As we conclude this Editorial, we would like to extend our deepest gratitude to all the contributing authors for their patience and persistence throughout the production process. We also wish to thank the Editorial Office team at *Chemical Engineering Research and Design* for their outstanding support, flexibility with deadlines, and careful management of every detail.

References

Anugraha, R.P., Pratiwi, V.D., Renanto, R., Juwari, J., Islami, A.N., Bakhtiar, M.Y., 2024. Techno-economic analysis of CO2 cryogenic distillation from high CO2 content gas field: a case study in Indonesia. Chem. Eng. Res. Des. 202, 226–234. https://doi.org/10.1016/j.cherd.2023.12.035.

Arenas-Grimaldo, C., Avendaño-Guerrero, J.G., Molina-Guerrero, C.E., Segovia-Hernández, J.G., 2024. Design and control of a distillation sequence for the purification of bioethanol obtained from sotol bagasse (Dasylirium sp.). Chem. Eng. Res. Des. 203, 11–17. https://doi.org/10.1016/j.cherd.2023.12.039.

Caballero-Sanchez, L., Vargas-Tah, A.A., Lázaro-Mixteco, P.E., Castro-Montoya, A.J., 2024. Recovery of 1,4-butanediol from aqueous solutions through aqueous two-phase systems with K2CO3. Chem. Eng. Res. Des. 201, 150–156. https://doi.org/10.1016/j.cherd.2023.11.015.

Du, L., Jin, S., Yang, Z., Sun, S., Yang, A., Shen, W., 2023. An efficient multi-criteria decision making for assessing the optimization of reactive extractive distillation in terms of economy, environment and safety. Chem. Eng. Res. Des. 197, 838–850. https://doi.org/10.1016/j.cherd.2023.08.033.

Feng, Z., Li, Q., Rangaiah, G.P., Leng, J., Fan, S., Wang, W., Dong, L., 2023. Economic and exergy analysis of three-product dividing-wall column and double liquid-only side-stream distillation processes. Chem. Eng. Res. Des. 200, 729–740. https://doi.org/10.1016/j.cherd.2023.11.022.

Geng, X., Xu, D., Hou, Z., Li, H., Gao, X., 2024. Novel dynamic control structure of reactive distillation process for isopropanol production via transesterification. Chem. Eng. Res. Des. 205, 131–147. https://doi.org/10.1016/j.cherd.2024.03.038.

Gholami, A., Kasiri, N., Khalili-Garakani, A., Segovia-Hernández, J.G., 2024. Enviro-economic investigation of novel heat-integrated configurations for pressure swing distillation. Chem. Eng. Res. Des. 204, 97–111. https://doi.org/10.1016/j.cherd.2024.02.033.

Gotama, B., Halomoan, T., Chen, Y.-Y., Lee, H.-Y., 2024. Energy saving design and control of side-streams reactive distillation configuration for diphenyl carbonate production process. Chem. Eng. Res. Des. 204, 316–329. https://doi.org/10.1016/j.cherd.2024.02.032.

Kang, H., Zhao, F., Zhu, R., Lei, Z., 2023. Extractive distillation for separation of isopropanol-n-propanol-water ternary system: mechanism analysis and process design. Chem. Eng. Res. Des. 200, 793–802. https://doi.org/10.1016/j.cherd.2023.11.036.

Kong, J., Dong, M., Zhang, Z., Yan, J., Li, J., Sun, L., 2024a. Design and control of fluid catalytic cracking gasoline fractionator. Chem. Eng. Res. Des. 203, 663–687. https://doi.org/10.1016/j.cherd.2024.02.007.

Li, M., Peng, J., Cheng, Y., Zhu, X., Ma, Y., Zhang, Z., Gao, J., 2023a. Dynamic control of an energy-saving process with two extractive dividing-wall columns for separation of acetone/methanol/butanone/tert-butyl alcohol mixtures. Chem. Eng. Res. Des. 200, 281–291. https://doi.org/10.1016/j.cherd.2023.10.045.

Li, Y., Yang, Z., Deng, X., Li, N., Li, S., Lei, Z., Eslamimanesh, A., Jin, S., Shen, W., 2023b. A mechanism-data hybrid-driven framework for identifying dynamic characteristic of actual chemical processes. Chem. Eng. Res. Des. 199, 115–129. https://doi.org/10.1016/j.cherd.2023.09.040.

Liu, J., Wang, S., Gao, P., Liu, S., Ma, Y., Xu, D., Zhang, L., Gao, J., Zhang, Z., Wang, Y., 2023. Energy-saving investigation of ester hydrolysis to alcohol by reaction extractive distillation process: from molecular insight to process integration. Chem. Eng. Res. Des. 198, 81–91. https://doi.org/10.1016/j.cherd.2023.08.041.

Nhien, L.C., Kim, G., Van Duc Long, N., Lee, M., 2024. Novel side-reactor dividing wall column and reactive distillation process for enhanced electronic-grade propylene glycol monomethyl ether acetate production. Chem. Eng. Res. Des. 208, 62–73. https://doi.org/10.1016/j.cherd.2024.06.011.

Regmi, C., Thamaraiselvan, C., Jebur, M., Qian, X., Wickramasinghe, R., 2024. Advancing produced water treatment: scaling up EC-MF-MDC technology from lab to pilot scale. Chem. Eng. Res. Des. 201, 157–168. https://doi.org/10.1016/j.cherd.2023.11.027.

Sun, S., Yang, A., Kong, Z.Y., Huang, H., Lv, L., Zhou, Q., Gu, B., 2024. The conceptual design and process intensification of the separation of ternary azeotropic mixture with heterogeneous characteristic. Chem. Eng. Res. Des. 204, 303–315. https://doi.org/10.1016/j.cherd.2024.02.047.

Udugama, I.A., Taube, M.A., Kirkpatrick, R., Bayer, C., Young, B.R., 2024. Implications for control systems in highly volatile energy markets: using a high purity distillation electrification case study. Chem. Eng. Res. Des. 203, 431–440. https://doi.org/10.1016/j.cherd.2024.02.001.

Wang, K., Xin, L., Zhang, Y., Qi, J., Zhu, Z., Wang, Y., Zhong, L., Cui, P., 2024. Sustainable and efficient process design for wastewater recovery of cyclohexane/isopropyl alcohol azeotrope by extractive distillation based on multi-objective genetic algorithm optimization. Chem. Eng. Res. Des. 201, 593–602. https://doi.org/10.1016/j.cherd.2023.12.004.

Wu, T., Wang, C., Liu, J., Zhuang, Y., Du, J., 2024. Design and 4E analysis of heat pump-assisted extractive distillation processes with preconcentration for recovering ethyl-acetate and ethanol from wastewater. Chem. Eng. Res. Des. 201, 510–522. https://doi.org/10.1016/j.cherd.2023.12.011.

Yang, Q., Xu, W., Li, J., Wang, Z., Xu, H., Zhou, M., Wang, Y., Li, X., Zhong, L., Cui, P., 2024. Molecular mechanism of efficient separation of isopropyl alcohol and isooctane by extractive distillation. Chem. Eng. Res. Des. 204, 269–281. https://doi.org/10.1016/j.cherd.2024.02.043.

Ye, G., Ye, M., Wu, X., Yan, Y., Ouyang, H., Han, X., 2023. Extractive distillation process using organic and ionic liquids for the separation of high-GWP refrigerant R410A: a thermodynamic and techno-economic assessment. Chem. Eng. Res. Des. 197, 558–571. https://doi.org/10.1016/j.cherd.2023.08.020.

Zhou, Z., Qi, M., Zhang, D., Cui, C., 2024. Insight into dynamic safety characteristics of extractive distillation process considering independent protection. Chem. Eng. Res. Des. 202, 248–266. https://doi.org/10.1016/j.cherd.2023.12.034.

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