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Editorial: Future perspectives on separation technologies

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Editorial on the Research Topic
Future perspectives on separation technologies

Humanity has encountered many global challenges throughout history. One of the most prevalent of these challenges today is the effect of a growing population and economy on the environment. For instance, the depletion of natural resources and the release of greenhouse gases that contribute to climate change have led to significant sustainability challenges. Since sustainability is primarily focused on human wellbeing and is inherently anthropocentric, it is essential to take immediate action to address these challenges. It is necessary to take action to avoid exceeding planetary boundaries, such as those related to climate change, ocean acidification, and loss of biodiversity. Technological advancements are essential to mitigating the pressures and impacts on sustainability, as they hold the key to meeting present needs without jeopardizing future generations' ability to meet their own.

Developing sustainable separation processes is crucial for achieving economic and environmental sustainability. Industrial separations can consume significant energy, and new or early-stage separation technologies can be prohibitively expensive. For example, nearly half of the total production cost is attributed to separations in producing fuels and chemicals derived from biomass. In the United States, industrial separations can consume up to 15% of total energy.

One of the most crucial sustainability issues we face today is climate change. To combat it, we must reduce carbon emissions caused by human activities, especially those associated with energy consumption. By doing so, we can lower the demand for separation energy, which in turn can help to decarbonize the chemical industry and mitigate the impacts of climate change.

Resource depletion, like fossil fuels, is a significant challenge to sustainability, alongside climate change. One way to address the issue is by substituting conventional petroleum-based fuels and chemicals with renewable alternatives derived from biomass. Nevertheless, the conversion processes for biomass are still in their early stages, with separations being a primary hurdle due to high expenses, intricate separation steps, and the presence of diluted product streams. Therefore, innovative separation technologies can provide solutions to the technical challenges of bioprocessing separation.

Developing sustainable separation processes can have multiple benefits, including reduced costs and energy demands, improved economic feasibility, and environmental advantages such as lowered greenhouse gas emissions. Additionally, such processes can lead to new separation methods and capabilities, which can enable emerging technologies that were previously impossible with existing separation technologies.

Separations are a crucial component of various industrial processes and contribute significantly to the attainment of many United Nations Sustainable Development Goals (SDGs), such as producing clean energy, promoting responsible production, and mitigating climate change. To move forward, it is essential to have a comprehensive dialogue within the scientific community.

The current Research Topic, "*Future perspectives on separation technologies*," consists of four articles that provide a broad overview of current and future scientific approaches concerning important separation technologies.

The topic is opened by Liu et al., who published their article entitled "*Methodology for assessing the maximum potential impact of separations opportunities in industrial processes*." The article presents an analysis of separation challenges faced by various industries, including bioprocessing, to identify opportunities for separation solutions with a focus on economic and energy considerations. To evaluate the potential impact of a separation challenge, an industrial screening process-based methodology was developed. The article highlights the importance of this methodology in gaining a better understanding of separation challenges and their feasible solutions. To evaluate the effectiveness of current and upcoming separation solutions, one can establish an "ideal" separator and calculate the minimum separation energy required. The insights gained from this assessment can then be utilized to assist in the selection or development of new separation technology solutions, taking into account various factors that may influence the expected benefits.

The article discusses 10 crucial separation challenges and highlights their significance. The evaluations uncovered areas for improvement such as reducing downstream equipment, creating new co-products, saving raw materials, and conserving energy. This data can aid in selecting separation technology solutions that can make the most of these advantages. In some instances, entirely new technologies may be necessary to realize the full potential of the identified opportunity. The assessment information can also potentially validate and guide the development of new technology.

Bohr et al. contributed with their review article entitled "*State-of-the-art review of porous polymer membrane formation characterization—How numerical and experimental approaches dovetail to drive innovation*." This paper delves into the significance of porous polymer membranes in promoting sustainable industrial processes. It emphasizes the importance of comprehending the membrane formation process for anticipating membrane functionality. Computational models and experimental techniques can be employed to characterize the phase inversion process. The review proposes a systematic approach that incorporates a uniform membrane performance data repository and the implementation of artificial neural networks to establish a correlation between membrane production parameters and membrane performance.

The third work of the current topic is about the important subject of direct air capture (DAC) of CO_2. Zeeshan et al. wrote a paper titled "*Direct air capture of CO_2: from insights into the current and emerging approaches to future opportunities*." The paper summarizes the current research on the latest liquid- and solid-based materials used to capture CO_2. The authors highlight the challenges associated with DAC technologies. While current research focuses on improving CO_2 working capacity sorption kinetics, it often overlooks cyclability and scalable DAC infrastructure design. Computational studies are required to accelerate the discovery of sorbent and the prediction of properties.

The authors also recommend future research directions to speed up the development of DAC systems. Specifically, they describe the desired characteristics of an ideal sorbent material that can effectively capture CO_2 from the air and release it for sequestration. The field is searching for a breakthrough sorbent with high selectivity, capacity, and stability under various conditions.

In the final work, Liu and Sun have combined the traditional approaches of separation processes with the benefits of artificial intelligence (AI) in their work titled "*Prospects of artificial intelligence in the development of sustainable separation processes*." In this article, the focus is on how Artificial Intelligence (AI) can assist in promoting sustainable separation processes. The article touches on the history of AI implementation and explores potential advantages and limitations. The article also highlights the future expansion of AI in separation science. With the fast advancement of AI, new possibilities have emerged in separation science. For example, AI algorithms can predict the characteristics of new materials, which can speed up the innovation process of sorbent materials. Machine learning can optimize operations by analyzing large datasets related to processes, thereby reducing energy wastage and improving error detection. Additionally, recent developments in large-scale language models based on scientific corpus have facilitated the quick selection of suitable separation techniques.

We hope that these articles will provide readers with valuable insights and inspire new ideas and approaches.

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