Electrospun Fiber-Based Membrane Condenser for Atmospheric Water Recovery

Issues | Water is extensively used in industry for various activities such as treatment, washing, dilution, heating, and cooling. In Europe, 58% of the water used comes from surface water resources, while 42% comes from groundwater. Industrial water withdrawals account for about 22% of global water consumption. Despite a recent 28% decrease in industrial water withdrawals, the long-term vision is for an innovative economy where natural resources are managed sustainably, including the recovery and reuse of water. Wastewater treatment methods have mainly focused on distillation, pervaporation, and reverse osmosis. However, significant amounts of water are still emitted into the air by chemical plants, cooling towers, power plants, etc., raising environmental concerns. Power plants must meet a growing demand for electricity and heat, leading to the emission of harmful air pollutants. In this context, separating water vapor from residual gas streams is essential. The "membrane condenser," a new membrane operation, offers a promising alternative by recovering water vapor from residual gas streams. This device shows encouraging results and opens new perspectives in various industrial sectors as a pretreatment to reduce contaminants.

Project Objective | The project aims to bring breakthrough innovation in the design of membrane condensers for atmospheric water recovery by developing membranes based on electrospun fibers functionalized with absorbents. This advancement departs from the conventional approach by offering a more efficient, specific, and economical method for selective water separation and capture. Furthermore, it will contribute to more sustainable water resource management.

Innovations | The project represents a major advancement by designing amphiphilic porous membranes specially adapted to the membrane condenser process. Until now, the membranes used were mainly intended for microfiltration and ultrafiltration. Developing membranes with the specific properties and structures required for the membrane condenser is crucial. High hydrophilicity/hydrophobicity balance, exceptional chemical resistance and stability against residual industrial gases, narrow pore size distribution, and improved structural and morphological characteristics are the key aspects to explore in this project, with electrospun membranes that can meet these requirements. Additionally, all approaches to improve mass transfer phenomena, control fouling issues and associated drawbacks such as clogging and hydrophobicity loss will be thoroughly studied in this project.

The second innovation involves integrating specific absorbents (MOF etc.) into these electrospun membranes to enhance their reversible water trapping capacity.

Experimental Work | The objectives include:

1. **Synthesis of Electrospun Membranes:**

- Preparation of polymer solutions (PVDF, PES, Chitosan, etc.) with different solvents.
- Electrospinning of membranes.
- Variation of experimental parameters such as voltage, flow rate, and distance between electrodes to optimize membrane properties.

2. Characterization of electrospun membranes:

- Contact angle measurement to evaluate membrane hydrophobicity.
- Morphology analysis by scanning electron microscopy (SEM) to study pore distribution and surface structure.
- Air permeability measurement to evaluate filtration performance.
- Modification of Membranes with Absorbents:

3. Finding suitable absorbents for effective integration into membranes.

- Adding absorbents during electrospinning or by post-synthesis surface modification.
- Characterization of modified membrane properties, such as absorption properties.
- Evaluation of Membrane Performance in a Membrane Condenser:

4. Assembly of an experimental device representative of a membrane condenser.

- Testing membranes under different gas flow and composition conditions to evaluate condensation efficiency.
- Monitoring the stability of membrane performance over time and in the presence of industrial contaminants.
- Study of Transfer Phenomena and Fouling:
- Measuring water vapor flux through membranes to quantify mass and energy transfers.
- Analyzing the composition of deposits and contaminants accumulated on membranes.
- Developing cleaning and regeneration strategies for membranes to minimize fouling and maintain long-term performance.