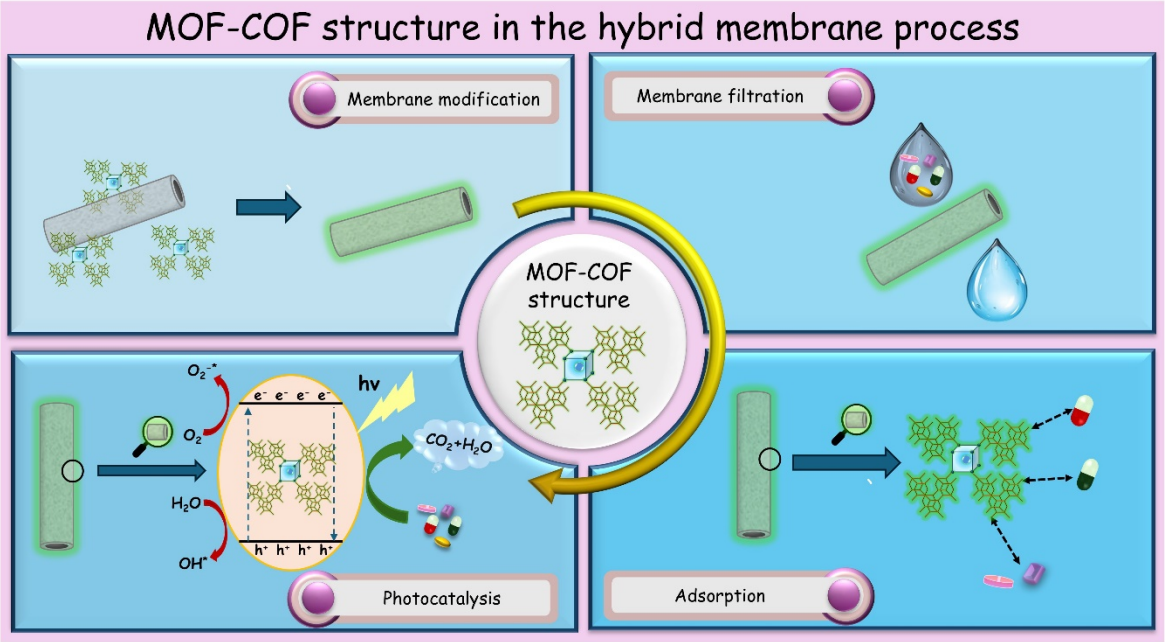
Multifunctional Next-Generation Membranes with Integrated MOF–COF Hybrids for Simultaneous Filtration, Adsorption, and Photodegradation

The contamination of surface and groundwater by so-called micropollutants – including pharmaceuticals – has become one of the greatest environmental challenges of the 21st century. Conventional water and wastewater treatment methods are often ineffective at removing these substances, leading to their accumulation in aquatic environments and posing potential threats to human health and ecosystems. In response, there is a growing interest in advanced water treatment technologies. Among the most promising are the concepts using filtration membranes, which can be modified to perform additional functions such as adsorption and photocatalysis.

The aim of this project is to develop and evaluate innovative micro- and ultrafiltration membranes enhanced with MOF-COF hybrid materials (metal-organic frameworks and covalent-organic frameworks). Thanks to their high surface area, ability to selectively capture pollutants, and photocatalytic activity, these materials allow for the efficient separation and simultaneous degradation of pharmaceutical contaminants. The project focuses on combining these two functions – adsorption and photocatalytic – within a multifunctional membrane. This integrated approach will not only improve water purification efficiency, but also enable membrane regeneration without the need for use of chemical cleaning agents.



The research will involve the synthesis and characterization of MOF-COF hybrid materials, their incorporation into both polymeric and ceramic membranes, and performance testing under laboratory and real-world conditions (including treatment of tap and surface water). Various operational strategies will be examined, including continuous and sequential modes (separate adsorption and photocatalysis stages), along with the influence of process parameters on pollutant removal efficiency. Special attention will be paid to the long-term durability and reusability of the modified membranes.

The motivation behind this project stems from the increasing demand for sustainable, multifunctional, and robust materials for water treatment – especially in light of the growing presence of micropollutants in the environment. Research on the application of MOF-COF hybrids in membranes is still very limited, giving this project a pioneering character.

The expected results will advance knowledge in the fields of chemical engineering, materials science, and membrane technology, while also supporting the development of more effective water purification methods. In the future, the project results could contribute to the implementation of innovative large-scale water treatment solutions.