Title of the PhD Project	The development of novel surface modification techniques to enhance the anti-biofouling properties of commercial membranes
Acronym	SModf_AntiBioFoul
Research Fields of the Project	Membrane Science and Technology; Material Science and Engineering; Chemical Engineering
Keywords	Surface modification, antibiofouling membrane, green cationic surfactant, membrane bioreactor
Host Institution, Department and Campus Location	İzmir Institute of Technology, Chemical Engineering Department
PhD Awarding Institution and Graduate Programme	İzmir Institute of Technology, Chemical Engineering Department
Name and Affiliation of Main Supervisor	Prof. Dr. Sacide Alsoy ALTINKAYA
Name and Affiliation of Co-Supervisors	Assoc. Prof. Dr. Sadiye VELİOĞLU
Research Environment and Infrastructure	IZTECH has all the facilities for membrane preparation, testing, and characterization. These facilities include membrane casting device, filtration set-up, surface charge, contact angle measurement devices, surface roughness, and morphological characterization tools. The MEM-CES laboratory at the Institute of Nanotechnology, Gebze Technical University (GTU) has three high-capacity workstations available for molecular simulation. Two of these workstations have 16 cores, while the third has 64 cores. Additionally, the lab is eligible to use the TRUBA cluster system, which offers high GPU and memory allocation for simulations.
Scientific Context of the Project	This study comprises three main parts. In the first segment, molecular dynamics simulations (MD) will be employed to screen various green cationic surfactants. The primary objective is to comprehend the relationship between the structure of the cationic surfactant and its antibacterial activity. Moving on to the second part, experimental studies will be conducted to validate the simulation results and identify optimal surfactant(s) for membrane preparation. The

	optimization process will be guided by the antibacterial activity of the surfactants against both Gram-positive and Gram-negative bacteria. In the third part, commercial membranes will undergo modification with the identified optimum surfactant(s) under different coating times and concentrations. The investigation will delve into the impact of coating conditions on the membrane's morphology. Furthermore, the study will explore the relationship between the morphological features of the membrane and its filtration performance through comprehensive characterizations. These characterizations will encompass thickness, porosity, pore size, contact angle of the membranes, FTIR, XPS, DSC, SEM, and AFM analyses. The antibiofouling property of the developed membranes will be assessed using model bacteria solutions as well as in a membrane bioreactor (MBR), simulating actual conditions in industrial MBRs.
Brief Workplan	Academic year of 2024-2025: Screening of cationic surfactants with molecular simulations Academic year of 2025-2026: Membrane development, morphological characterization and filtration tests in a small unit Academic year of 2026-2027: Membrane filtration tests in a pilot-scale unit
Innovative Aspects of the Project	Membrane fouling is a critical issue for the application of membrane technology. Among various fouling types, biofouling has been regarded as the most serious one, decreasing the membrane flux and causing irreversible deposition of living microorganisms and sub sequent cohesive biofilm formation on membrane surfaces. The strategies commonly used to control biofouling in membrane processes include biocide dosing, pretreatment of feed to reduce nutrient availability, chemical and physical cleaning and new membrane development or modification of existing membranes to make them less prone to biofouling. Among these strategies, the fabrication of antibiofouling membranes through surface modification stands out as an attractive alternative. This is particularly appealing as other solutions often involve high costs, delicate operations, and the use of toxic chemicals. The primary techniques employed for surface modification to impart low-biofouling properties to the surface include interfacial polymerization, photo-initiated surface grafting, plasma treatment, coating a thin protective layer on the membrane, and surface modification of polymer membranes with nanoparticles. The application of thin-film and self-assembled coatings typically results in decreased water permeability, attributed to the presence of a thick polymer layer that poses mass transfer resistance. UV-grafting is specific to membranes, and plasma treatment may pose challenges or be costly when applied in a manufacturing environment. Over the last decades, mussel-inspired polydopamine (PDA) has received significant interest in membrane modification. This is due to its material-independent surface functionalizing capability and the presence of catechol and amine groups. These constituents not only render the surface hydrophilic but also facilitate additional chemical modifications. There are 2 approaches employed to control biofouling in terms of material design. Anti-adhesion approaches aim to reduce the initial macromolecular adsorption or

	attachment of organisms, while antimicrobial approaches target, disperse, or suppress the activity of attached organisms. Classic cationic surfactants derived from quaternary ammonium groups are often used for their antimicrobial properties in developing antibacterial membranes. However, their use raises significant environmental concerns due to their limited biodegradability and toxicity to aquatic organisms. The slow biodegradation of these compounds enhances their toxicity, as aquatic organisms experience prolonged exposure. Currently, synthetic cationic amino acid-based surfactants are emerging as promising alternatives to traditional cationic surfactants. Structurally similar to native lipopeptides, these compounds are cationic amphiphiles composed of one or two amino acids linked to a hydrophobic moiety. Achieving an optimal balance between hydrophobicity and polarity is crucial for sufficient antibacterial activity. This study aims to improve biofouling resistance of commercial membranes by employing a two-step approach. The first involves surface modification with polydopamine (PDA) deposition, followed by the grafting of green cationic amino acid-based surfactants. Different surfactant designs will be systematically screened using a combination of experimental and theoretical methods to elucidate the relationship between surfactant structure and inhibitory mechanisms. The project's novelty lies in the development of a new class of green surfactants capable of enhancing biofouling resistance in commercial membranes. Another innovative aspect of the proposed study is the surface modification protocol designed to minimize flux decline.
Training Opportunities of the Project	In CNR-ITM, PhD students will have access to the laboratory equipment including membrane casting machine, micro-, ultra- and nanofiltration rigs and advanced characterisation and analytical equipment (scanning electron microscopy, contact angle, mechanical test machine, FT-IR and porometer). The students will have also full access to open internet and full free access to scientific journals. The annual meeting organized by the Institute (ITM Seminar Days) can be used by the PhD students as a platform to present their work. The scientific facilities of Center of Applied Research at Karlsruhe consist of different bench scale and technical scale membrane testing units, CDI development kit, analytical devices. The students will receive training on the operation of a membrane bioreactor and conducting membrane tests in a pilot-scale unit. At Tufts University, students will undergo comprehensive training in various research skills focused on the development of new self-assembling membrane materials for water and wastewater treatment. This training encompasses synthesis and characterization, membrane manufacturing and testing, surface engineering and analysis, as well as scalable manufacturing of membrane products. Researchers will have access to state-of-the-art instrumentation both in the laboratory and on campus to support their work.

Interdisciplinary Aspects	This project integrates three interdisciplinary fields: membrane science and technology, chemical engineering, and material science and engineering. The expertise required for membrane development, surface modification, and characterization—focusing on filtration capacity and morphological features such as pore size distribution and surface charge—necessitates a background in membrane science. Additionally, proficiency in both theoretical and experimental tools for membrane characterization will require an approach rooted in both Chemical Engineering and Material Science and Engineering.
Intersectoral Mobility ☐ **Short Visit** ☐ **Secondment**	
International Academic Secondment	Host Supervisor: Associate Professor Ayse Asatekin Host Institution: Tufts University Host Department: Chemical and Biological Engineering Duration: 6 months Estimated Time of Mobility: 2025 Host Supervisor: Dr. Alberto Figoli Host Institution: Institute on Membrane Technology (CNR-ITM) National Research Council of Italy Duration: 6 months Estimated Time of Mobility: 2026 Host Supervisor: Professor Jan Hoinkis Host Institution: Karlsruhe University of Applied Sciences Duration: 6 months Estimated Time of Mobility: 2027

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