

Polymeric membrane impregnation in the environment of supercritical carbon dioxide – process parameters selection, interaction modelling and biofouling study

Membrane bioreactors are currently one of the most popular solutions in the food and pharmaceutical industries or in wastewater treatment plants. They are an integrated device in which the process occurring in the bioreactor (e.g. microbiological production of antibiotics, biodegradation of organic compounds contained in wastewater) is supported by a membrane process. In this most classic solution, a micro- or ultrafiltration membrane is used to concentrate the biomass in the reactor. The higher the concentration of biomass, hence (in a certain range) the process proceeds proportionately faster. The retention of the cells through the membrane allows obtaining a homogeneous permeate (a stream passing through the membrane) free from any solid contaminants.

One of the main difficulties encountered in working with a membrane bioreactor and hence pointed as a disadvantage of this type of bioreactor is the instability of the permeate stream over time. It results from the depositing of the layer of retained matter (fouling) on the surface of a membrane. By definition, biomass should be concentrated in the retentate stream, but even a high flow rate and a heedful membrane material choosing or a membrane additional impregnation do not bring satisfactory results. Biomass deposition is particularly troublesome. Cells on such surface create a biofilm which is covered by a glycocalyx (a protective layer) produced by these cells. Biofilm is then extremely difficult to remove and it generates high flow resistances causing the decrease of a permeate stream even to the value close to zero. Therefore, every major chemical engineering conference, not to mention membrane conferences, has a session devoted to solving the problem of fouling.

One of the methods for biofouling control is to give the membrane bacteriostatic properties through membrane surface modification which can effectively inhibit the growth of microorganisms. This study will provide the first scientific report on the modification of polymer membranes' performances by their functionalization with selected antibacterial substances using supercritical solvent impregnation (SSI) with carbon dioxide. SSI is a novel technique that complies with the Green chemistry rules by avoiding organic solvent usage, eliminating solid waste and effluent and minimizing energy requirements. This technique is unique and based on advantageous transport properties of supercritical fluids (high densities, low viscosity, zero surface tension, high diffusion coefficients) which provide deep penetration of a supercritical fluid into the polymer matrix and impregnation of the whole polymer volume with an active substance. Thus, SSI provides fabrication of materials that cannot be produced by any other technique.

The aim of this study is to identify the SSI process parameters for functionalization the polymeric membranes made of cellulose acetate, polyamide and polysulfone, with thymol, carvacrol and silver lactate as active substances with strong antimicrobial activity against a broad spectrum of microorganisms. The impact of the process parameters (pressure, temperature, decompression rate, process duration) and polymers properties as the type of monomer molecule and average molecular weight, on the active substance loading, will be thoroughly investigated. The electrostatic interactions of thymol and carvacrol with functional groups of a given polymer will be modeled in order to describe the physical changes of the functionalized membranes.

In the second part of the research, an influence of the active substance loading on membranes' behavior in a bioreactor will be investigated. Membranes' permeability, resistance to biofouling caused by cells or other compounds of the culture medium and the effect of the active substance on the membrane on bacteria growing in a bioreactor will be observed. Based on the obtained data a mathematical model will be derived with the aim to describe the functionalized membranes fouling process.

Results obtained in this project will present a contribution to material science, membrane separation processes, and biofouling control. Obtained data on the SSI processing of selected polymers and interactions between the active substances and polymer matrix can be used not only in the fabrication of functionalized polymer membranes but also in the fabrication of medical devices, hygienic materials, and systems for the controlled release.