Ultrafiltration of protein based solution.Study of membrane fouling

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Introduction

Membrane processes are widely used for water treatment- for example- for desalination, rectification, wastewater treatment or purification operations. The use of such processes is justified by the mild condition in which the separation takes place (temperature and pressure), the low energy consumption compared to other processes which are used for the same outcome, the continuous possibility of separation and the possibility of avoiding the use of additives. A significant issue of the process is the presence of unwanted molecules in the filtrated solution, which reduce or affect the process performances. Membrane processes are subject to fooling in presence of certain solutions, especially containing proteins or amino-acids.

Membrane fouling is a phenomena in which suspended particles or molecules from the liquid phase start to deposit or adsorb on the surface of the membranes and/or in their pores. Membrane fouling causes filtration flux to decline and, in some cases, to completely obstruct pores of the membrane. This influences membrane performances and in consequence, the final results of the process.

Our current work is devoted to ultrafiltration of protein solution and its impact on filtration performance but also adsorption on the membrane and denaturation of the protein after filtration. The filtration process takes place using vitamin B12 (as model molecule to follow the membrane selectivity performances) and one protein (lysozyme) in an experimental set-up working with high flow velocity and different transmembrane pressures.

Material and methods

Filtration of the studied solutions was performed with a ceramic UF membrane. This commercial membrane (tubular, TiO_2, cut-off 1 kDa) is placed in a laboratory-scale pilot [1]. The solutions are filtrated at different pressures, while maintaining a constant flow rate and temperature. For each test, the hydraulic and selectivity membrane performances are measured in order to quantify the impact of protein adsorption on the membrane.

Results and discussion

Previous works have shown that vitamin B12-water solution can be used to follow the membrane performances with no impact on the membrane condition. It was also previously shown that proteins are adsorbing in the membrane pore, reducing the membrane performances and facilitating membrane fouling. In this study, filtration

tests of lysozyme (15 kDa protein) and vitamin VB12- water solutions were performed according to the sequence presented bellow.

Table 1. Sequence of filtration tests with respective concentration, observed rejection rate and hydraulic permeability

Protein Solution	**Concentration (mM)**	**R max (%)**	**Lp (10^{-14}m^3.m$^{-2}_{memb}$)**
VB12	9,22E-03	57	4.1
Lysozyme	**0,025**	**85**	3.6
Lysozyme	**0,025**	**93**	3.3
VB12	9,22E-03	75	3.2
Lysozyme	**0,025**	**98**	3.1
Lysozyme + VB12	**0,025** / 9,22E-03	**99** / 81	2.8
Lysozyme + VB12	**0,025** / 9,22E-03	**100** / 87	2.3
VB12	9,22E-03	86	2.3

As a general trend, it is observed that, after each filtration the rejection rate of the lysozyme increases while the membrane permeability decreases (Table 1). Even after two successive filtrations of the same molecule, an increase in the rejection rate is observed, indicating an adsorption of the molecule at the surface or in the pores. Further tests confirmed the behavior of the membrane in terms of rejection and hydraulic permeability. Rejection rates of vitamin B12 show that the pore size selectivity increases as protein filtrations are performed (i.e. average pore radius decreases from 1.6 nm to 1.1 nm estimated with the Nernst-Planck modeling for uncharged molecule).

Additional analysis of the permeate and retentate by High-Pressure Liquid Chromatography, shows that (even with a low membrane cut off of 1 kDa) the permeate contains lysozyme under two forms : native and denatured, while the retentate displays only native lysozyme population. The presence of the denaturated lysozyme in the permeate can be assumed to facilitate the adsorption in the membrane pores. The adsorption of the lysozyme molecule was also confirmed by FTIR-ATR analysis. The infrared analysis showed an increase of the adsorption of the molecule with time.

Conclusion

The current study investigated the evolution of membrane performances with successive filtration of protein based solutions. The finding of this study showed indeed that membrane performances decrease due to protein adsorption at the membrane surface and in the pore. The transmitted proteins are denatured facilitating the adsorption and agglomeration phenomena.

References

1. J. Bikai et al. Compte Rendus Chimie 2015, vol 18, pp. 56-62