Effect of salinity and nanoparticle polydispersity on retention and UF membrane fouling

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Keywords: Ultrafiltration; nanoparticles; fouling; fluorescence; polydispersity; salinity.

Introduction

Nanoparticles (NPs) retention by ultrafiltration (UF) membrane presents a great interest since few decades due to the emergence of this new pollution in natural waters used to produce drinking water. Some studies already showed that specific NPs are efficiently retained by UF (Troester et al. 2016). However, this retention is strongly dependent of water composition and chemistry. Presence of salts can affect the stability of NPs suspensions and lead to aggregation or repulsion phenomenon which can induce a modification of NP retention. In this study, the NP retention have been studied with the filtration of NP suspension with size close to or smaller than membrane pore size. The influence of salinity and polydispersity of the feed suspensions on NP retention was analyzed and compared to simplified NP suspension. To deepen this work, the location of membrane fouling after filtration experiment was determined by Confocal Laser Scanning Microscopy (CLSM). This location of the fluorescent signal allowed to identify the membrane retention zone(s), to estimate fouling mechanisms operating during the filtration and to determine the penetration profile. Moreover, it is possible to distinguish the fouling contribution of each size of NP with or without salt. Microscopic observations were compared to fouling mechanisms found with application of Hermia models on flux data observed during the experiment.

Material and Methods

Ideal suspensions of fluorescent calibrated NPs with size of 10 (NP-10) and 1.5 nm (NP-1.5) were filtered until a volume concentration factor of 200. Filtrations were realized with NP-10 and NP-1.5 filtered individually, simultaneously and with the adding of 50 mmol.L^{-1} of NaCl. Ultrafiltration membranes used are PES multichannel hollow fiber (ALTEON I, Aquasource, SUEZ, France) with nominal pore size of 20 nm. The efficiency of the membrane and the quantity of NP remained blocked in and/or on the membrane were estimated by NPs retention measurements. Location of the fluorescence signal emitted by NPs in and/or on the membrane was visualized by CLSM and penetration profiles of NPs have been determined. The use of NPs with different fluorescent emission wavelengths allowed to distinguish each size of NPs in membrane material. Location of fluorescent signal of NPs have been correlated with macroscopic permeate flux data to validate fouling mechanism(s) operated during the filtration experiment. Finally, influence of transmembrane pressure (TMP) was studied on retention rate and fouling establishment and location.

Results and Discussion

Retention rate of NP-10 filtered individually is not modified with the adding of NP-1.5, salinity or both whatever the TMP applied. This retention rate stays superior or equal to 99% while the NPs size is twice smaller than nominal pore size. However, the adding of NP-1.5 or/and salinity changes the location of NP-10, leading to a strongly increase of NP-10 quantity remained blocked at the membrane like the increase of TMP. Retention rate of NP-1.5 has been modified by each factor added (salinity and/or NP). Increase of TMP, adding of NP-10 and adding of salinity lead to a decrease of NP-1.5 retention. Repulsion charge effects facilitate the passage of NP-1.5 through the membrane. Retention rate estimated by mass balance shows an increase of retention rate of each NPs size versus the time. The establishment of membrane fouling which lead to a better selectivity can explain this higher retention. Visualization of fouled membrane by CLSM and measurement of penetration profile show that the retention of NP-10 is operated mainly on membrane surface and in the membrane skin while NP-1.5 fluorescent signal is detected on membrane surface into the skin and the support. Concerning NP-1.5, the adding of NP-10 and NaCl leads to a cake formation including NP-1.5 on membrane material. The participation of NP-1.5 to the deposit on membrane surface is increased with presence of NP-10 and salinity due to the retention of NP-1.5 by the cake formed by NP-10.

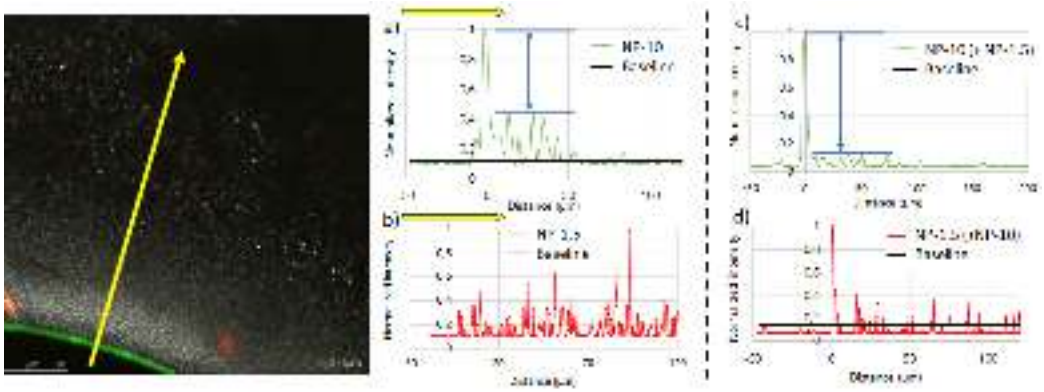

Figure 1. MCBL imagery of membrane fouled by NP-10 (in green) and NP-1,5 (in red) and penetration profiles obtained after a filtration of monodisperse (a, b) and polydisperse suspension (c, d)

Conclusions

The adding of salinity (50 mmol.L^{-1}) or/and NP-1.5 not strongly involve the NP-10 retention by UF membrane but the quantity remained blocked on membrane surface was increased importantly: the fouling model, cake filtration, appears earlier. At the opposite, retentions of NP-1.5 were decreased by adding of NP-10, salinity and TMP increase. The part of NP-1.5 which stays blocked in the membrane is decreased and the recovery in the permeate is increased when salinity or/and NP-10 are added in feed suspensions. It is the first time that the fouling contribution of each size of NP is detailed on the penetration profile of NP.

Acknowledgment

"The project leading to this publication has received funding from Excellence Initiative of Aix-Marseille University - A*MIDEX, a French "Investissements d'Avenir" programme. It has been carried out in the framework of the Labex MEC."

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