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INVESTIGATION OF CLEANING PERFORMANCE AND MECHANISMS OF *BACILLUS CEREUS* SPORE REMOVAL DURING AN ALKALINE CLEANING OF A TUBULAR CERAMIC MICROFILTRATION MEMBRANE

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ABSTRACT

The significance of biofouling problems and its control in membrane filtration processes (MF, UF, RO) is now well recognized. This study focuses on the first (attachment) phase of biofouling. We have investigated experimentally the cleanability of a 0.45 µm tubular ceramic microfiltration in terms of both hydraulic and microbiological cleanlinesses and examined the interrelationship between the two types of cleanliness. Hydraulic cleanliness was evaluated using three parameters : percent flux recovery (FR), percent irreversible removed fouling (RF) and a hydraulic cleanliness criterion (HCC, i.e. $(R_n-R_m)/R_m < 0.05$). Microbiological cleanliness was assessed by the measurement of the residual microbial population adhered onto the membrane surface left after cleaning. *Bacillus cereus* spores isolated from a food processing line were selected as a model microorganism. A single-stage cleaning consisted of the recirculation in turbulent flow regime at 4 m/s of a 0.5 wt% sodium hydroxide solution with a cleaning time varying from 5 to 30 min. The adhered spore population along the membrane path was evaluated by ultrasonication of seven 5-cm long membrane pieces in a nonionic surfactant followed by enumeration on nutrient agar, and was expressed as the median of $\log_{10}$ (CFU/cm²) values.

During microfiltration of the spore suspension (ca. 10^5 CFU/ml in a phosphate buffer), a constant transmembrane pressure of 0.75 bar, crossflow velocity of 4 m/s produced a steady state flux within two hours. The initial contamination was found to be uniform along the membrane as shown by an analysis of variance ($p>0.05$) and was centered on 5.2 log (CFU/cm²), which was suitable to the cleaning kinetic study.

The hydraulic membrane resistance changes during cleaning fitted a first order kinetics which predicted a useful cleaning duration close to 10 min above which membrane resistance was quasi-constant. The detrimental effect of time on cleaning efficiency was highlighted: the hydraulic membrane permeability could not be restored beyond a cleaning duration of 15 min due to the redeposition on the membrane surface of spore cells previously released in the cleaning solution. A simple model (first order reaction) combining removal and deposition rates provided a fairly good fit of the variation with time of the adhered spore population ($r=0.98$, $p<0.0001$, $n=11$). The adhered population left after cleaning was positively correlated with the hydraulic cleanliness criterion, HCC ($r=0.65$, $p<0.05$, $n=12$). Nevertheless residual contamination was not statistically correlated ($p>0.05$) neither with the standard percent flux recovery nor with the measured fouling resistance left after cleaning ; futhermore the spore redeposition process occuring beyond 10 min of cleaning did not result to a parallel increase in the membrane resistance. This indicates that complex interactions (possibly nonlinear effects) take place between the hydraulic and microbiological cleanlinesses. From a practical point of view, the flux recovery alone proved to be little sensitive to the detection of residual microorganisms deposited on a ceramic microfiltration membrane and representing a potential risk of contamination.