Functionalised electrospun nanofibres for removal of pathogens

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The electrospinning technique is a process for making continuous nanofibres in a non-woven form. This process spins fibres ranging from 80 nm diameter to several hundred nanometers. The non-woven structure is produced by applying a high voltage to the anode, submerged in a spinning solution. This produces a charged jet of fluid when the electrical force is higher than the surface tension of the solution and the fibres are collected on a grounded aluminium plate (Ahn et al., 2005).

Nanofibres have a small pore size and a large surface area to volume ratio compared to nonwovens (this ratio for a nanofibre can be as large as 103 times of that of a microfibre). This, together with their low density and interconnected open pore structure, make the nanofibre nonwoven appropriate for a wide variety of filtration applications (Huang et al., 2003). One of the potential applications of the nanofibres is water filtration. Due to the large effective surface areas, nanofibres can carry functional agents with different properties, such as biocides. With microfiltration membranes it is possible to retain suspended solids and micro-organisms. The added value of the tested nanofibre microfiltration membranes functionalized with silver nanoparticles (nAg) or other biocides to pathogen removal was studied.

The biocides used in this study are commercially available, WSCP for example, is used as a cooling tower biocide and is applied directly into the water. Silver nanoparticles are nowadays implemented in a wide variety of consumer products for antimicrobial control. The aim of the study is to examine the effectiveness of different biocides and the possibility to electrospin them in a steady state nanofibre membrane.

Materials and methods

Electrospinning and functionalisation

The electrospinning set-up used in this study is a scaled up multi nozzle system, which is is developed at Ghent University (Decostere et al., 2009)). The functional agents used in the experiment are commercial biocides and silver nanoparticles. The membranes were functionalised by adding nAg or commercial biocides (WSCP, bronopol, DBNPA, TCMTB) to the polymer solution before the electrospinning process starts. In this way the biocides are impregnated into the membrane. The added concentrations are expressed as on mass fibre percent (omf%) and were added in a range from 1 -5 omf%.

Removal of pathogens

To evaluate the removal of pathogens water samples were taken from waste water from a general hospital (10^7-10^9 colonie forming units / 100 ml). The samples were filtered with a pressure filter (1-1.5 bar). Further the culturable micro – organisms were enumerated by inoculation in a nutrient agar culture medium (www.oxoid.com) at 37°C (EN ISO 6222,1999).

Results

The results of the enumeration of culturable micro organisms (37°C) represented in Figure 1. Enumeration values are represented as log10 values.

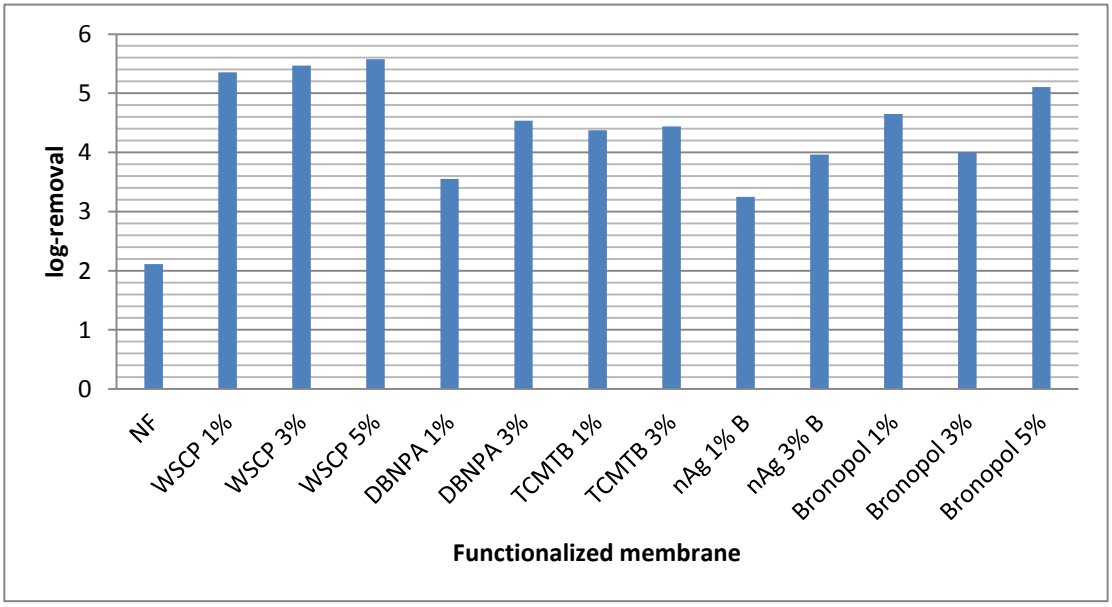

Figure 1.1 Removal of pathogens with functionalized and non-functionalized membranes. NF = non functionalised, WSCP= functionalised with WSCP (1, 3 or 5%), DBNPA= functionalised with DBNPA (1 or 3%), TCMTB= functionalised with TCMTB (1 or 3%), bronopol= functionalized with bronopol (1,3 or 5%), nAg = functionalised with Ag nanoparticles,

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The results show that due to the silver nanoparticles and the functionalisation with biocides in the functionalized membrane a higher efficiency (3,9 $\log_{10}$ –5,5 $\log_{10}$) could be achieved. Further, the removal of pathogens is a factor 100 (2 $\log_{10}$) higher with a WSCP (5%) than conventional microfiltration. Functionalisation with Ag nanoparticles gave a 4 $\log_{10}$ removal. It is generally known that these particles only have effect on gram negative bacteria such as E. coli. Gram positive bacteria are not affected by these nanoparticles. WSCP and bronopol are bactericides that can be applied on electrospun nanofibres and it has also effect on gram positive bacteria (Chen et al., 2008). The removal with a non-functionalised membrane is not as good as other micro-filtration studies. With other commercial membranes a 2 $\log_{10}$ – 4 $\log_{10}$ removal is possible (Gómez et al., 2006, Ghayeni et al., 1999, Zodrow et al., 2009). This is probably due to the deformation of the nanofibres during pressurized filtration.

References

Ahn, Y.C., Park, S.K., Kim, G.T., Hwang, Y.J., Lee, C.G., Shin, H.S., Lee, J.K. (2005). Development of high efficiency nanofilters made of nanofibers. Current Applied Physics, 6, 1030-1035.

Chen, L., Bromberg, L., Hatton, A. and Rutledge, G.C. (2008). Electrospun cellulose acetate fibres containing chlorhexidine as a bactericide. Polymer, 49, 1266–1275.

Decostere, B., Daels, N., De Vrieze, S., Dejans, P., Van Camp, T., Audenaert, W., Hogie, J., Westbroek, P., De Clerck, K., Van Hulle, S. (2009). Performance assessment of electrospun nanofibres for filter applications, *Desalination*, accepted.

EN ISO 6222:1999, Water quality – Enumeration of culturable micro-organisms – Colony count by inoculation in a nutrient agar culture medium

Gómez, M., de la Rua, A., Garralón, G., Plaza, F., Hontoria, E., Gómez, M.A. (2006). Urban wastewater disinfection by filtration technologies. Desalination, 190, 16 -28

Huang, Z.-M., Zhang, Y.-Z., Kotaki, M., Ramakrishna, S. (2003). A review on polymer nanofibers by electrospinning and their applications in nanocomposites. Composites science and technology, 63, 2223-2253.

Sadr Ghayeni, S.B., Beatson, A.J. and Schneider, R.P. (1999). Bacterial passage through microfiltration membranes in wastewater applications. Journal of Membrane Science, 153, 71-82

Zodrow, K., Brunet, L., Mahendra, S., Li, D., Zhang, A., Li, Q., Alvarez, P.J.J. (2009). Polysulfone ultrafiltration membranes impregnated with silver nanoparticles show imporved biofouling resistance and virus removal. Water research, 43, 715-723..