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Impact of cross flow velocity on biofilm formation potential and particle size distribution along the membrane surface

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Impact of cross flow velocity on biofilm formation potential and particle size distribution along the membrane surface

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Abstract Two types of Nanofiltration membranes had been used to study the influence of cross flow velocity on biofouling. Filtration had been conducted at constant transmembrane pressure and variable cross flow velocity (0.3, 0.8, 1.9 and 5.1 m/s). The higher cross flow velocity had decreed the rate of fouling in the order of (1.3, 1.5 and 1,6) and (1.8, 2 and 4.33) for both types of membrane, while the achieved reduction in the concentration of the active biomass on the membrane surface had reached the order of (1.4, 1.68 and 1.65) and (2.2, 1.64, and 1.98) respectively. The impact of the particle size was more severe in the last section of the membrane due to the reduction in the size and the increase in particle number, while the impact of the biomass was more in the initial portions of the membrane.

Key words: Nanofiltration; fouling; flux; particle size; biomass

INTRODUCTION

With the proven success of membrane technology in water treatment, Still the membrane fouling in its various forms (Colloidal, organic, scaling and biofouling) (Deborah *et al.*1996,Avloniti *et al.*,2003) is the main limiting factor in the field of water treatment. While the material that fouls membranes is diverse, and is composed of inorganic particles, natural organic mater (NOM), and bacterial/fungal/algal/protozoan cells (Al-Ahmad., *et al.*1993). The rate and extent of fouling is a strong function of the quality of water. Fouling will lead to higher operational cost, higher energy demand, and reducing the life time of the membrane elements (Vrouwenvelder *et al.*,2003). In general, fouling occurs either on the surface of a membrane or within its pores. Many methods had been practiced to reduce fouling, work in this area has focused on surface modification, by addition of disinfectants, anti scaling agents, and increasing the pretreatment of the feed water before it reaches the membranes. However, these are not remedies to the problem, and fouling remains a key area in definite need for improvement.

Membrane pretreatment

Sand filtration, active carbon beds and chlorination process are among the most practiced membrane pretreatment processes. The potential of the biological approach as a pretreatment process to reduce the colloidal and organic constituents that either contributes directly into fouling or it may provide nutrients like carbon sources for the development of biofilms inside the membrane surfaces is ecologically sounded (Flemming *et al.*,1997).The ability to release the microbial soluble products and sloughed biomass had been considered the main limitation of any biological treatment (Crespo *et al.*,2004, Muncan Mara and Nigel Horan.2003 and Sarina *et al.*,2004) because it can promote microbial growth in the down stream unit.

In this research we had investigated the impact of various cross flow rate on formation of cake resistance due to the compounds that could be present in the biologically treated ground water, by characterizing the compounds into particle size and active biomass along the membrane surface.

Materials and methods

Preparation of suspended biomass

Rich suspended biomass water had been obtained in a 200L Denitrification tank, the denitrification rate (C:N:P) was in the order of (10:5:1), contaminated ground water with 60 mg/l Nitrate had been collected from Bisamberg - in the North of Vienna-Austria. The water riche biomass had been decanted from the denitrification tank; the large agglomerated flocks had been removed by passing the water through sieve opening of 0.5 mm, before it had been feed to the membrane cell unit.

Membrane unit and membrane types

Different cross flow velocity had been carried out in a flat sheet membrane cell having an area of 0.0148 m^2 with dimensions of (260 x 57), the cell had been designed in five equal separate sections, each section with a permeate out let.

The prepared rich suspended biomass water had been filtered at constant Transmembrane pressure of 5 bar and different cross flow velocity (0.3, 0.8, 1.9 and 5.1 m/s) for two different types of Nanofiltartion membranes NF90 and NF270 from Filmtech company.

Measurement and characterizing of the detached mass from membrane surface

The duration of each filtration test was around 2 hours. The used membrane had been divided into 5 pieces; each piece identical to the area of each section it had covered. Detachment of the particles (biomass, organic and inorganic) from the membrane surface had been conducted by a series of five repeated low energy sonications, each for duration of 5 minutes in autoclaved distilled water. The effective particle size distribution of the detached particles for each piece had been measured with Dynamic light scattering instrument (Zeta pals 90, BrookHaven instrument cooperation).

The concentration of biomass of the detached particles is determined as adenosine triphosphate ATP, ATP analysis is based on extraction of the compounds from biomass using a nucleotide-releasing agent followed by the light-generating luciferine–luciferase reaction. The generated light signal is measured as relative light units (RLU) after a 2 s delay time and a 10 s integration time with a luminometer (Berthold). we had measured for the same released mass, the electrical conductivity (EC), Assimilable organic Carbon (AOC), UV_{254} and TOC.

Results

The impact of cross flow velocity on membrane fouling and its influence on the removal of the accumulated particles in its various forms (organic inorganic and biomass) are listed in table 1.

The values of cake resistance had decreased linearly in the order of (1.3, 1.5 and 1,6) for the NF90 membrane and order of (1.8, 2 and 4.33) for the NF270 for the higher cross flow velocities (0.8, 1.9 and 5.1 m/s) in comparison with 0.3 m/s. The accumulated ATP had decreed almost in the order of (1.4, 1.65 and 1.68) and (2.2, 1.64, and 1.98) for the NF90 and NF270 membranes respectively. The UV_{254} value had been decreased for membranes in the order of (1.4, 2.4 and 1.4) and (0.78, 1.55 and 1.55).

Table 1 The influence of cross flow velocity on the characteristics of cake resistance.

Type	m/s	EC		UV_{254}		Particle size		Cake resitance		ATP	
		µS	STD	A	STD	nm	STD	1/m	STD	RLU	STD
NF90	0.3	31.6	30.59	0.501	0.18	1623	166.51	3.62E+14	1.85E+13	4.49E+06	1.13E+06
NF90	0.8	28.8	10.76	0.354	0.06	1790	147.78	2.79E+14	7.59E+12	3.19E+06	7.18E+05
NF90	1.9	22	8.92	0.211	0.04	2011	151.20	2.41E+14	5.33E+12	2.68E+06	4.15E+05
NF90	5.1	27	8.80	0.389	0.09	1764	363.04	2.29E+14	5.88E+12	2.72E+06	9.02E+05
NF270	0.3	29.4	18.30	0.273	0.07	1861	170.97	1.78E+14	1.43E+13	4.42E+06	1.21E+06
NF270	0.8	30	20.68	0.348	0.07	1935	313.22	9.95E+13	6.84E+12	2.05E+06	8.46E+05
NF270	1.9	19.2	2.86	0.176	0.05	2103	174.80	8.61E+13	6.39E+12	2.70E+06	7.19E+05
NF270	5.1	20	3.74	0.177	0.02	1679	394.33	4.11E+13	2.87E+12	2.23E+06	3.32E+05

The average value of the particles size for the membrane over all surface area (0.0148 m^2) where insignificant, But we could elaborate the results of the particle size and its impact on the membrane fouling for each cross flow velocity, by evaluating the particles size for each specific section of the membrane as in figure 1.

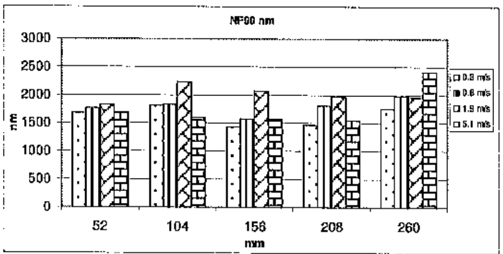

Figure 2 Particle size distributions along the membrane surface

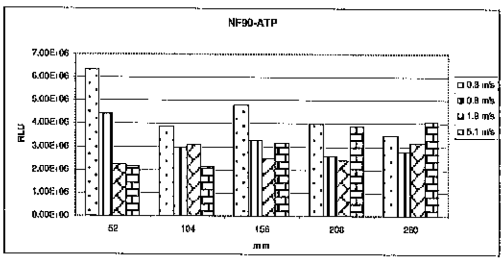

Figure 3 ATP concentrations along the membrane surface

The water characteristic is in dynamic changes as it passes along the membrane surface, where the effective particle size in the first 0.003m^2 is higher comparatively with the last section for both the membranes, except the last run at 5.1 ms^{-1} the particle size and the ATP concentration had increased. From this results could find also the correlation between the particle size and the ATP concentration as in Figure 2, and the dominant type of fouling along the membrane surface. The influence of cross flow velocity on membrane fouling of each section of the membrane surface had been indicated in figure 3 and 4 for both membranes, where the average enhancement in flux for NF90 had reached a values of (1.3, 1.5 and 1.6) times higher than 0.3 ms^{-1} flow velocity and for NF270 the enhancement in flux had reached a values of (1.8, 2 and 4.33) times higher.

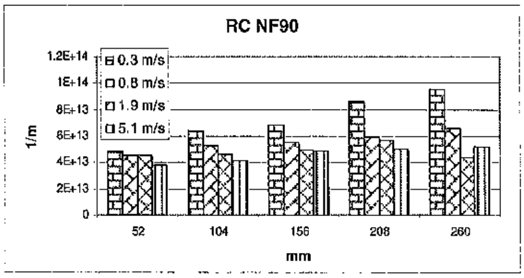

Figure 3 Particle size distributions along the membrane surface

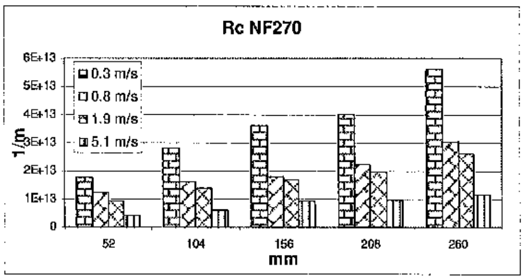

Figure 4 ATP concentrations along the membrane surface

Conclusion

The potential of biofouling had been decreased at the higher cross flow velocity, since the concentration of the active biomass had decreased In the order of (1.4, 1.65 and 1.68) and (2.2, 1.64, and 1.98) for NF90 and NF270 membranes at cross flow velocities of (0.8, 1.9 and 5.1 m/s), while the organic compounds had been decreases on the order of (1.4, 2.4 and 1.4) and (0.78, 1.55 and 1.55). Hitherto the fluxed had been enhanced in the order of (1.3, 1.5 and 1.6) and (1.8, 2 and 4.33) for both membranes.

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