Application of Filtration in Seawater and Stormwater Treatment

by

MD. ABU HASAN JOHIR

University of Technology, Sydney

A thesis submitted to fulfilment of the requirements for the degree of
Master of Engineering

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NOMENCLATURE

A	=	The membrane surface area (m^2)
ANZECC	=	Australian and New Zealand Environment and Conservation Council
ASTM	=	American Standard Testing and Methods
BMP	=	Best Management Practice
BOD	=	Biochemical Oxygen Demand
BTSE	=	Biologically treated sewage effluent
BOM	=	Biodegradable Organic Matter
C_b	=	The concentration of particles in a feed water
COD	=	Chemical Oxygen Demand
Da	=	Dalton
DOC	=	Dissolved Organic Carbon
DOM	=	Dissolved Organic Matter
DAF	=	Dissolved air flotation
DMF	=	Dual media filter
kDa	=	Kilo dalton
EfOM	=	Effluent Organic Matter
GAC	=	Granular Activated Carbon
EPS	=	Extracellular Polymeric Substances
HPSEC	=	High Pressure Size Exclusion Chromatography
IE	=	Ion Exchangers
kPa	=	Kilo Pascal
m.bar	=	Millibar
MFI	=	Modified Fouling Index
MWD	=	Molecular Weight Distribution
MF	=	Microfiltration
MFI-UF	=	Modified fouling index by using ultra filter membrane

MFI-NF	=	Modified fouling index by using nano filter membrane
MWCO	=	Molecular Weight Cut-off
M_w	=	Weight Average Molecular Weight
M_n	=	Number Average Molecular Weight
NF	=	Nanofiltration
NOM	=	Natural Organic Matter
NTU	=	Nephelometric Turbidity Unit
PAC	=	Powdered Activated Carbon
R_m	=	Membrane resistance
RO	=	Reverse Osmosis
SEC	=	Size Exclusion Chromatography
SS	=	Suspended Solids
SWOM	=	Seawater Organic Matter
t	=	Filtration time (s)
THM	=	Trihalomethanes
TDS	=	Total Dissolved Solid
TMP	=	Trans-membrane Pressure
UF	=	Ultrafilter
ULPRO	=	Ultra Low-pressure Reverse Osmosis Membranes
V	=	Total permeate volume (l)
ZVI	=	zero-valent iron
ΔP	=	Applied trans-membrane pressure (Pa)
η	=	Water viscosity at 20^0C (N s/m^2)
α	=	The specific resistance of the cake deposited
ρ	=	Polydispersity
^{0}C	=	Degree Celsius

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CERTIFICATE OF AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for any degree nor has it been submitted as part of requirements for a degree except as fully acknowledge within the text.

I also certify that the thesis has been written by me. And help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

Signature of Candidature

Md. Abu Hasan Johir

Sydney, July 2009

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Md. Abu Hasan Johir

ABSTRACT

Water scarcity is becoming a significant problem throughout the world and the creation of new sources of potable water has been a significant issue worldwide and as a consequence harvesting of stormwater and desalination have become two of the most vital and valuable alternative resources in many countries around the world. Membrane based separation systems (such as reverse osmosis) have been widely used to produce potable water. In membrane separation system membrane fouling is major problem which results in deterioration in membrane performance, lessens membrane life time and increases total cost to treatment plants. As a result, suitable pre-treatment is required which can significantly minimize fouling problems to membrane filtration technique.

The main aim of this study was to assess relative performance of filtration systems as pre-treatment to seawater and stormwater. The pre-treatment systems that were used in this study were deep bed filter (single medium and dual media), fibre filter and hybrid filter (fibre filter followed by media filter). They were assessed in terms of turbidity and organic matter removal, and head loss build-up. The efficiency of the filter as pre-treatment was evaluated in terms of Silt Density Index (SDI) and Modified Fouling Index (MFI).

In this study, two different water sources were used (namely seawater and stormwater). Seawater was chosen mainly for its organic matter together with dissolved solids and stormwater was chosen for highly colloidal substances. Four representative pre-treatments were examined to find out their effectiveness as pre-treatment to different water sources (seawater and wastewater). Another attractive and environmentally friendly pre-treatment of biofilter was not studied in this research as there was concurrent research performed in our laboratory (Chinu et al. 2008)

From the filter experimental results on seawater, it was found that the turbidity removal was high and all the deep bed filters produced more or less the same quality water. There was a slower buildup of head loss for coarser filter medium. The result showed that finer filter media (sand) and dual media filter with filtration velocity of 5 m/h exhibits 70% of turbidity

removal efficiency. The high rate fibre filter used with in-line flocculation removed the 70-80% of turbidity. The turbidity was decreased to 0.16 - 0.49 NTU by fiber filter. The pressure drop (ΔP) on fibre filter with and without in-line flocculation was 33 and 4 mbar respectively. The use of in-line flocculation improved the performance of these filters as measured by the MFI and SDI. After pre-treatment with contact flocculation-filtration and fibre filter the MFI and SDI_{10} value reduced from 138-256 s/L^2 to 0.77-2.95 s/L^2 and from 7.40-8.75 to 2.4-4.8 respectively. On the other hand, the headloss development on dual media filter in hybrid filter system with in-line flocculation of influent seawater to the fibre filter was 11.0 cm. In addition, when different pre-treatment hybrid systems were operated at different filtration velocities (5 and 10 m/h), the MFI and SDI_{10} was reduced to 1.4-3.6 s/L^2 and 2.6-3 respectively. A post treatment of reverse osmosis (RO) after an inline-flocculation-dual media filtration showed lower normalized flux decline (J/J_0) (0.35 to 0.22 during the first 20 hours operation) while, seawater without any pre-treatment showed steeper flux decline (0.18 to 0.11 within 20 hours operation) of RO.

The application of deep bed filters, fibre filter and hybrid filter as pre-treatment to stormwater was also experimentally investigated in detail. It was found that the removal efficiency for turbidity, suspended solids and TOC was found to be 95-98%, 99 % and 40-60 % respectively at a flocculant dose of $FeCl_3$ of 15 mg/L. The phosphorous removal efficiency was relatively good (up to70%). The removal efficiency for heavy metals such as Cd, Pb, Cr and Ni was found to be very low for all tested filtration systems because concentrations of these metals in the influent were also low. These filters can be used as a pre-treatment to micro/ultra filter. This is demonstrated through MFI measurements. The MFI was reduced from 750-950 s/L^2 (for stormwater) to 15-9 s/L^2 (for filtered effluent). Detailed submerged membrane filter experiments conducted with pre-treated water (after dual media filtration) showed that the membrane filter can successfully be used as post-treatment to in-line flocculation-filter at a sustainable flux of 10 L/m^2.h to remove the remaining solids and pathogens. An increase of air scouring in the membrane unit decreased the pressure development although it did not have any effect on increasing the critical flux beyond 10 L/m^2.h.