MEMBRANE HYBRID SYSTEM IN HIGH QUALITY WATER REUSE

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A Thesis submitted in fulfillment of the requirements for the degree of Doctoral of Philosophy

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June 2015

CERTIFICATE OF ORIGINAL AUTHORSHIP

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

I also certify that the thesis has been written by me. Any 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.

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ACKNOWLEDGEMENTS

I take this opportunity to thank the people those who have helped me directly and indirectly to make this endeavor a reality.

First of all, I would like to express my deep appreciation and gratitude to my principle supervisor, Professor. Saravanamuthu Vigneswaran for the valuable patient guidance, kind advice you gave to me all the way from securing the Ph.D program to its completion. I was really fortunate to have you as my supervisor. The entire process would not have been possible without your great support and encouragement.

I also would like to thank my co-supervisor Dr. Tien Vinh Nguyen for his valuable friendly advice, assistance and guidance during my study. I really appreciate Dr. Jaya Kandasamy, for his help throughout my study from the beginning to its completion. My gratitude also goes to Dr. P. Loganathan during the later stage of my study. I also thank Dr W. G. Shim, Dr Christian Kazner, Dr Stuart Khan and Dr James McDonald during my study. I appreciate Andrzej Listowski, Manager, Water treatment plant, Sydney for his assistance for providing water samples for experiments. Thanks for my friends Johir, Danious, Sanjeev, Jeong, Chung, Gayathri for sharing research experience and helping during my study.

I would like to thank CRC CARE, Andrew Beveridge, Program leader, CRC CARE, and University of Technology, Sydney for funding assistance.

My heartfelt thanks to my family without whom none of this work would have been accomplished. Thanks for my parents and parents-in-laws for your great physical and moral support provided during the study period. I am really thankful to my loving parents for giving me the best things in my life and I really appreciate your continuous support, encouragement and dedication since my childhood. I really thank my little

prince, my son for your wonderful support; your gorgeous smile, since you were 8 weeks old, keeps me energized throughout the day. You were the only motive for the completion of my study. I can't simply thank my husband who married me during my study and the challenges you faced, hardships you underwent cannot be put it in words. Thanks for being with me as my whole strength and a supportive man behind my accomplishments. I am truly thankful for having you in my life.

ABSTRACT

Although membrane filtration treatment for water reclamation is becoming more widespread, the challenges such as membrane fouling, high cost, management of concentrate, and incomplete removal of organic micro pollutants still prevail. This study presents technical alterations to minimize such issues via the development of pre-treatments techniques where fluidized bed contactors and membrane hybrid systems were used. Granular activated carbon (GAC) and an ion exchange resin (Purolite A502PS) were used as adsorbents for the above mentioned pre-treatments respectively. Biologically treated sewage effluent (BTSE) collected from a water reclamation plant, Sydney was used as a feed water for these experiments. The operational conditions such as fluidization velocity and adsorbent dosage of fluidized bed columns strongly influenced the removal of dissolved organics (DOC). GAC was found to be more effective in removing organics compared to Purolite A502PS. This could be due to the competition provided by other inorganic anions present in BTSE for Purolite exchange sites. Plug flow model was successfully used to predict the impact of the amount of adsorbent and of the flow rate on the removal of organic matter.

A similar trend was observed when another pre-treatment technology of membrane hybrid system was used. Micro filtration (MF) – GAC hybrid system effectively removed hydrophobic organics, hydrophilic organics and organic micro pollutants, whilst, the removal of inorganic ions was minimum. Comparatively, the performance of MF-Purolite hybrid system was less efficient in DOC removal; however the removal of sulfate and nitrate ions was good. In both membrane hybrid systems, the addition of adsorbents directly into the membrane reactor reduced membrane fouling by membrane surface scouring and adsorption. Overall, the performance of membrane-GAC adsorption hybrid system was more effective than membrane-ion exchange hybrid

system. Based on this, MF-GAC was suggested to combine with nano filtration (NF) system. Here second membrane filtration of NF was to further polish pre-treated BTSE in terms of dissolved organics, organic micro pollutants and for some divalent ions removal. This treatment system is referred as 'dual membrane hybrid system' i.e., the combination of MF-GAC adsorption hybrid system followed by NF. Traditionally RO is used as a polishing step in dual membrane systems in waste water reclamation plants. The use of NF instead of RO is found to be cost effective in terms of energy requirements. This dual membrane hybrid system is suggested to produce high quality water reuse where the removal of monovalent ions is not necessary; however the selection of treatment system depends on the requirements of recycled water for end purposes. For example, the recycled water used for irrigation requires sodium adsorption ratio of 3-9 for wide range of salt tolerant crops. Therefore, a study was conducted to determine whether the BTSE can be treated using nanofiltration (NF) and reverse osmosis (RO) to bring these risk parameters within safety limits, because the NF treated BTSE could bring SAR levels only up to 14. As per the results, it was suggested to blend NF and RO permeate in equal proportions to produce a product quality suitable for irrigation with SAR value below 10. Utilizing NF prior to RO reduced the RO membrane fouling and both NF and RO removed most of the organic micro pollutants from BTSE and this may subsequently protect soil and ground water from potential hazards.

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ABBREVIATIONS

AC	Activated carbon
AER	Anion exchange resin
ANZECC	Australian and New Zealand Environment and Conservation Council
AOC	Assimilable organic carbon
ATP	Adenosine tri phosphate
BAC	Biological activated carbon
BOD	Biological oxygen demand
BTSE	Biologically treated sewage effluent
CEC	Critical Environmental concentrations
CFU	Colony forming unit
CMF	Continuous micro filtration
COD	Chemical oxygen demand
DBPs	Disinfection by products
DOC	Dissolved organic carbon
EC	Electric conductivity
EDCs	Endocrine distrupting compounds
EfOM	Effluent organic matter
EPA	Environmental protection agency
F-EEM	Fluorescence excitation emission matrices
FTIR	Fourier transform infrared spectroscopy
GAC	Granular activated carbon
HA	Humic acid
HRT	Hydraulic retention time
HSDM	Homogenous surface diffusion models
IER	Ion exchange resin
IMS	Integrated membrane systems
LC-OCD	Liquid chromatography organic carbon detection
LMW	Low molecular weight
LPRO	Low pressure reverse osmosis
MBR	Membrane bio reactor
MCC	Membrane correlation coefficient
MF	Micro filtration
MIEX	Magnetic ion exchange
MSFD	Multi-stage flash distiller
MW	Molecular weight
MWCO	Molecular weight cutoff
NF	Nano filtration
NOM	Natural organic matter
NSAIDs	Non-steroidal anti-inflammatory drugs
PAC	Powdered activated carbon
PhAC	Pharmaceutically active compounds

PPCPs	Pharmaceuticals and personal care products
RO	Reverse osmosis
ROC	Reverse osmosis concentrate
SAR	Sodium adsorption rate
SDI	Silt density index
SEM	Scanning electron microscope
SMPs	Soluble microbial products
SWRO	Sea water reverse osmosis
TDS	Total dissolved solids
TMP	Transmembrane pressure
TOC	Total organic carbon
TSS	Total suspended solids
UF	Ultra filtration
VOCs	Volatile organic compounds
WHO	World health organization
WRP	Water reclamation plant
WWTP	Wastewater treatment plant