# DEVELOPMENT OF MAGNETOPHORETIC ACTUATION COMPOSITE MEMBRANES FOR REMOVAL OF HUMIC ACID

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**UNIVERSITI SAINS MALAYSIA**

**2016**

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**by**

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**Thesis submitted in fulfillment of the**
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## ACKNOWLEDGEMENT

With earnest gratitude and appreciation, I would like to express my deepest and most heart-felt gratitude to my beloved parents and siblings for their unequivocal support throughout all the difficult situations during the period of my entire study.

It is my great pleasure to express my deepest appreciation and gratitude to my dedicated supervisor Dr. Low Siew Chun and co-supervisors Prof. Abdul Latif Bin Ahmad and Assoc. Prof. Lim Jit Kang for their excellent supervision, enormous effort spent in guiding, invaluable advice, practical view, and helping me throughout my PhD studies. My achievement of this research project is a reflection of prominent supervision works from my supervisors.

In particular, I would like to show my gratitude to all the laboratory technicians and administrative staff of the School of Chemical Engineering, Universiti Sains Malaysia for the assistance rendered to me.

On top of that, I would like to convey heartfelt gratitude and thanks to all my beloved friends and colleagues: Siew Hoong, Peck Loo, Man Kee, Wei Ming, Zhi Hua, Choon Ming, Hui Yen, Swee Pin, Sim Siong, Susan, Jing Yao, Huey Ping, Zeinab, Chuan Chun, Arthur, Qian Yee, Peng Chee, Atiah, and Wani for their encouragement, kindness and support towards me. Last but not least, the financial support given by Ministry of Higher Education (MOHE) and Universiti Malaysia Perlis (UniMAP) is gratefully acknowledged.

**NG QI HWA,**

**June 2016**

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| AFM | Atomic force microscopy |
| BSA | Bovine serum albumin |
| CAB | Cellulose acetate butyrate |
| CIP | Clean-in-place |
| DBPs | Disinfection by-products |
| DI | Deionized |
| DLS | Dynamic light scattering |
| EC | Electrocoagulation |
| EDS | Energy dispersive spectroscopy |
| EO | Electro-oxidation |
| FA | Fulvic acid |
| FESEM | Field emission scanning electron microscopy |
| F-MNPs | Functionalized-magnetite nanoparticles |
| HA | Humic acid |
| HAAs | Haloacetic acids |
| HCl | Hydrochloride acid |
| HS | Humic substance |
| IR | Infrared |
| LCST | Lower critical solution temperature |
| MF | Microfiltration |
| MNPs | Magnetite nanoparticles |
| MWCO | Molecular weight cut-off |
| NaOH | Sodium hydroxide |

| | |
|---|---|
| NF | Nanofiltration |
| NMP | N-methyl-pyrrolidone |
| NOM | Natural organic matter |
| P(St-AA-NVP) | Poly(styrene-acrylic acid-N-vinylpyrrolidone) |
| PA | Polyamide |
| PAI | Polyamideimide |
| PDDA | Poly(diallyldimethylammonium chloride) |
| PEM | Polyelectrolyte multilayer |
| PES | Polyethersulfone |
| PLC | Programmable logic controller |
| PMAA | Poly(methacrylic acid) |
| PNIPAAm | Poly(N-isopropylacrylamide) |
| PSS | Poly(sodium-4-stryene sulfonate) |
| PVDF | Polyvinylidene fluoride |
| PVP | Poly(N-ethyl-4-vinylpyridinium bromide) |
| QCM-D | Quartz crystal microbalance with dissipation |
| RO | Reverse osmosis |
| SDI | Slit density index |
| SSR | Sum of squared residuals |
| TEM | Transmission electron microscopy |
| TFC | Thin film composite |
| TGA | Thermogravimetric analysis |
| THMs | Trihalomethanes |
| TOC | Total organic carbon |
| TSP | Trisodium phosphate |

| | |
|---|---|
| UF | Ultrafiltration |
| UV | Ultraviolet |
| VSM | Vibrating sample magnetometer |
| WHO | World health organization |
| WM | With external oscillating magnetic field |
| WOM | Without external oscillating magnetic field |
| XPS | X-ray photoelectron spectroscopy |
| XRD | X-ray diffraction |

## LIST OF SYMBOLS

| | |
|---|---|
| A | Effective membrane area |
| $A_o$ | Amplitude |
| B | Magnetic field strength |
| C | Mass sensitivity constant of the QCM-D |
| $C_p$ | Permeate concentration |
| $C_F$ | Feed concentration |
| $C_{cr}$ | Specific critical salt concentration |
| D | Dissipation factor |
| $\Delta D$ | Change in the dissipation factor |
| $E_{dissipated}$ | Dissipated energy |
| $E_{stored}$ | Energy stored in the oscillating quartz crystal |
| f | Resonant frequency |
| $\Delta f$ | Change in frequency |
| $h_0$ | Thickness of the crystal |
| $h_l$ | Film thickness |
| Ha | Hartmann number |
| J | Membrane flux at time t |
| $J_o$ | Membrane initial flux |
| k | Fouling coefficient |
| $K_b$ | Complete pore blocking coefficient |
| $K_c$ | Cake filtration constant |
| $K_i$ | Intermediate pore blocking coefficient |
| $K_s$ | Standard pore blocking coefficient |

| | |
|---|---|
| $L$ | Characteristic length scale |
| $M_s$ | Saturation magnetizations |
| $\Delta m$ | Change in mass adsorbed per unit surface of the quartz crystal surface |
| $n$ | Dimensionless filtration constant |
| $\eta$ | Overtone number |
| $\eta_1$ | Film viscosity |
| $\eta_3$ | Viscosity of the bulk liquid |
| $\rho_o$ | Density of the crystal |
| $\rho_1$ | Film density |
| $\rho_3$ | Density of the bulk liquid |
| $R$ | Rejection percentage |
| $R_a$ | Mean roughness parameter |
| $Re$ | Reynold number |
| $R_q$ | Root mean square roughness parameter |
| $R_z$ | Mean difference between five highest peaks and lowest valleys |
| $t$ | Time |
| $\tau$ | Decay time |
| $U_E$ | Electrophoretic mobility |
| $\mu$ | Dynamic viscosity |
| $\mu_1$ | Film elasticity |
| $V$ | Cumulative volume of filtrate |
| $V_{max}$ | Maximum volumetric capacity |
| $\dot{V}$ | Filtrate volume collected through an available membrane area |
| $\omega$ | Angular frequency of the oscillation |
| $\dot{\gamma}$ | Shear rate |