

## Table of Contents

<b>Certificate</b>	<i>iii</i>
<b>Acknowledgement</b>	<i>vi-vii</i>
<b>Table of Content</b>	<i>vii</i>
<b>List of Tables</b>	<i>xii</i>
<b>List of Figures</b>	<i>xiii</i>
<b>List of Abbreviation</b>	<i>xvi</i>
<b>Preface</b>	<i>xviii</i>

<b>CHAPTER NO</b>	<b>TOPIC</b>	<b>PAGE NO</b>
<b>CHAPTER 1</b>	<b>INTRODUCTION</b>	<b>1-21</b>
1.1	Water Availability and Demand	1
1.2	Wastewater Treatment	2
	1.2.1 Technologies available for contaminant removal	3
1.3	Membrane Technology	6
	1.3.1 Membranes and Membrane Technology	8
	1.3.2 Mechanism of Membrane Separation	9
	1.3.3 Nanocomposite Membrane	11
1.4	Degradation and separation of heavy metal using nano-composite membrane	12
	1.4.1 Chromium and its removal	12
1.5	Broad Objectives of the present work	15
1.6	Reference	16
<b>CHAPTER 2</b>	<b>LITERATURE REVIEW</b>	<b>22-79</b>
2.1	Nano-particles: Preparation, Characterization and Applications	22
2.2	Nano-particles as Photo-catalysts	24
2.3	Photocatalytic removal of pollutant using green synthesized nanoparticles	28
2.4	Nanocomposite film/membrane	35
2.5	Removal of Hexavalent Chromium (Cr(VI))	41
2.6	Photo-catalytic Membranes and their Application	47
2.7	Effect of nanoparticle loading on the performance of	53

	membrane and photo catalyst application	
2.8	Challenges and Shortcomings in the existing wastewater treatment technology	56
2.9	Objective of present work	57
2.9	Reference	59
<b>CHAPTER 3</b>	<b>SYNTHESIS AND CHARACTERIZATION OF NANOPARTICLE AND NANOCOMPOSITE MEMBRANE</b>	<b>80-111</b>
3.1	Introduction	80
	3.1.2 Theory of Membrane Formation	83
	3.1.2.a Phase Diagram and Thermodynamic parameter	83
	3.1.2.b Kinetic parameter	85
3.2	Experimental Procedure	86
	3.2.1 Material	86
	3.2.2 Method	87
	3.2.2.a Synthesis of TiO <sub>2</sub> Nanoparticles (NPs)	87
	3.2.2.b PVDF/TiO <sub>2</sub> composite membranes preparation	87
	3.2.3 Determination of Thermodynamic Parameter	89
	3.2.4 Determination of Kinetic Parameter	90
	3.2.5 Membrane characteristics	90
	3.2.6 Characterization Technique	91
3.3	Results and Discussion	92
	3.3.1 Particle and Membrane characterization	92
	3.3.1.a High Resolution Transmission Electron Microscope (HRTEM) Results	92
	3.3.1.b X-Ray Diffractometer (XRD) Finger Prints	93
	3.3.1.c Fourier Transform Infrared (FTIR) Spectra	94
	3.3.1.d Diffusive Reflectance Spectroscopy: Optical band gap analysis	96
	3.3.2 Phase Diagram	97
	3.3.3 High Resolution Scanning Electron microscopy (HRSEM)	103
	3.3.4 Porosity, Pore size, and Hydrophilicity of Membranes	105
3.4	Conclusion	107
3.5	Reference	107

**CHAPTER 4 ANTIFOULING BEHAVIOUR OF PVDF/TiO<sub>2</sub> COMPOSITE MEMBRANE: A QUANTITATIVE AND QUALITATIVE ASSESSMENT 112-143**

4.1	Introduction	113
4.1.2	XDLVO Theory	115
4.2	Experimental Procedure	117
4.2.1	Material	117
4.2.2	Synthesis of TiO <sub>2</sub> NPs and PVDF/TiO <sub>2</sub> composite membranes	118
4.2.3	Physiochemical Properties of Membranes	118
4.2.3.a	Contact Angle Measurement	118
4.2.3.b	Morphological Characterization	118
4.2.3.c	Antibacterial Characteristics	119
4.2.3.c.a	Halo Zone Test	119
4.2.3.c.b	Bacterial Growth	119
4.2.4	Water Permeation Studies	120
4.3	Results and Discussion	121
4.3.1	Physiochemical properties of the membrane	121
4.3.1.1	AFM Analysis	121
4.3.2	XDLVO Theory based Analysis of Fouling Behaviour	124
4.3.3	Antibacterial Property	127
4.3.3.a	Halo Zone Test	127
4.3.3.b	Bacterial Growth	128
4.3.4	Permeate Flux	132
4.3.4.a	Performance against BSA	132
4.3.4.b	Performance against HA	133
4.4	Conclusion	136
4.5	Reference	137

**CHAPTER 5 SYNTHESIS OF PVDF/TiO<sub>2</sub> MEMBRANES AND THEIR ANTIFOULING BEHAVIOUR DURING ULTRAFILTRATION 144-161**

5.1	Introduction	144
5.2	Experimental Procedure	146
5.2.1	Material	147
5.2.2	Synthesis of TiO <sub>2</sub> NPs and PVDF/TiO <sub>2</sub> composite membranes	147
5.2.3	BSA Adsorption Experiment	147
5.2.4	Quantification of fouling	147

5.2.5	Fouling Resistance	149
5.2.6	Hermia's Model of Fouling	149
5.3	Results and Discussion	152
5.3.1	BSA Adsorption Test	152
5.3.2	Water Permeation	153
5.3.3	Comparison of Experimental Results with Predictions using Hermia's Model	156
5.4	Conclusion	159
5.5	Reference	159
<b>CHAPTER 6</b>	<b>HEXAVALENT CHROMIUM REMOVAL USING BI-FUNCTIONAL NANOCOMPOSITE MEMBRANES</b>	<b>162-200</b>
6.1	Introduction	162
6.2	Experimental Procedure	165
6.2.1	Material	165
6.2.2	Synthesis of TiO <sub>2</sub> NPs and PVDF/TiO <sub>2</sub> composite membranes	165
6.2.3	Characterization	165
6.2.4	Membrane performance	165
6.2.4.a	Rejection of Cr (VI)	165
6.2.4.b	Photocatalytic reduction of Cr (VI)	166
6.2.3.c	Analysis of Cr(VI) concentration	167
6.2.5	Response Surface Methodology and Optimization analysis.	168
6.2.5.a	Experimental design using RSM	168
6.2.5.b	Validation	170
6.2.6	Stability and Reusability of Nanocomposite Membrane	171
6.2.7	Performance of membrane in real wastewater	171
6.3	Results and Discussion	172
6.3.1	Mechanism for Cr(VI) removal from wastewater using bi-functional membrane	172
6.3.2	UV spectra of feed, permeate, retentate Cr (VI) solution and after photocatalytic reduction	173
6.3.3	Effect of Various Parameter	174
6.3.3.a	Effect of Particle Loading	174
6.3.3.b	Effect of Particle size	176
6.3.3.c	Effect of pH	177
6.3.3.d	Effect of Cr concentration	179

	6.4.3.e	Effect of Transmembrane Pressure	181
6.3.4		RSM and ANOVA analysis	182
	6.3.4.a	Data adequacy check of the model	182
	6.3.4.b	Effect of independent (process) variables on % Rejection	183
	6.3.4.c	Effect of independent (process) variables on % Reduction	185
	6.3.4.d	Optimization and validation of optimized results	188
	6.3.5	Reusability and Stability	189
	6.3.6	Performance of Membrane using real waste water	191
6.4		Conclusion	195
6.5		Reference	196
<b>CHAPTER 7 SUMMARY AND SUGGESTION FOR FUTURE WORK</b>			<b>201-203</b>
<b>LIST OF PUBLICATION</b>			<b>204-206</b>