

CONTENTS

	PAGE
ACKNOWLEDGMENTS	ii
ABSTRACT	iii
ABSTRAK	iv
CONTENTS	v
LIST OF TABLES	xi
LIST OF FIGURES	xiii
APPENDIX	xv
Chapter 1: Introduction	1
1.1 Significance of Research	1
1.2 Industrial Wastewater and Heavy Metal Pollution	2
1.3 Various Techniques of Treatment Technology	4
1.3.1 Chemical Precipitation	4
1.3.2 Ion Exchange	5
1.3.3 Evaporation	6
1.4 Membrane Separation	6
1.4.1 Reverse osmosis	9
1.5 Comparison of Different Separation Technologies	11

1.6 Objective and Scope of Research	13
Chapter 2 : Literature Review	15
2.1 Nickel	15
2.1.1 Uses of Nickel	16
2.1.2 Nickel in Vegetation	16
2.1.3 Distribution and Behaviour of Nickel in the Aquatic Environment	19
2.1.3.1 Nickel in Streams and Rivers	19
2.1.3.2 Nickel in Lakes	21
2.1.3.3 Nickel in Estuaries	22
2.1.3.4 Nickel in Wastewater	22
2.1.4 Toxicity of Nickel	23
2.1.4.1 Effect of Nickel on Marine Organisms	23
2.1.4.2 Effect of Nickel on Freshwater Organisms	26
2.1.5 The Effect of Nickel on Human Health	28
2.1.6 Recommended Environmental Quality Standards (EQS)	31
2.2 Chromium	33
2.2.1 Chromium in Vegetation	35

2.2.2 Distribution and Behaviour of Cr in Aquatic Environment	36
2.2.2.1 Chromium in Streams and Rivers	36
2.2.2.2 Chromium in Wastewater	38
2.2.3 Toxicity of Chromium	38
2.2.3.1 Effect of Chromium on Marine Organisms	38
2.2.3.2 Effect of Chromium on Freshwater Organisms	42
2.2.4 The Effect of Chromium on Human Health	46
2.2.5 Recommended Environmental Quality Standards (EQS)	49
Chapter 3 : Materials and Methods	51
3.1 Membrane Separation	51
3.1.1 Chemicals	51
3.1.2 Preparation of Metal Solutions	51
3.1.3 Membrane Unit	52
3.1.4 Reverse Osmosis Membrane Module	55
3.2 Metal Analysis	56
3.2.1 Chemicals	56

3.2.2 Inductively Coupled Plasma	57
3.2.3 Flame Photometer	59
Chapter 4 : Results and Discussions	62
4.1 Separation of Nickel (II) Sulfate	62
4.1.1 NiSO_4 : Trans-membrane Pressure Drop and Permeate Flow Rate	62
4.1.2 NiSO_4 : Trans-membrane Pressure Drop and Ni in Permeate	66
4. 1. 3 NiSO_4 : Transmembrane Pressure Drop and Ni in Concentrate	69
4.1.4 NiSO_4 : Flow Rate and Ni Concentration in Permeate	72
4.2 Separation of Nickel (II) Chloride	75
4.2.1 NiCl_2 : Trans-membrane Pressure Drop and Permeate Flow Rate	75
4.2.2 NiCl_2 : Trans-membrane Pressure Drop and Ni in Permeate	78
4.2.3 NiCl_2 : Trans-membrane Pressure Drop and Ni in Concentrate	81

4.2.4 NiCl_2 : Flow Rate and Ni Concentration in Permeate	83
4.3 Separation of Chromium (III) Chloride	86
4.3.1 CrCl_3 : Transmembrane Pressure Drop and Permeate Flow Rate	86
4.3.2 CrCl_3 : Trans-membrane Pressure Drop and Cr in Permeate	89
4.3.3 CrCl_3 : Trans-membrane Pressure Drop and Cr in Concentrate	92
4.3.4 CrCl_3 : Flow Rate and Cr Concentration in Permeate	95
4.4 Conclusion	97
Chapter 5 : A Feasibility Study of Membrane Process	101
5.1 A Comparative Study on RO Membrane Process and Deionization	101
5.1.1 An Automatic Water Demineralizer/Deionizer	102
5.1.2 Reverse Osmosis Membrane Unit	103
5.2 Conclusion	104

Chapter 6 : Modelling - Surface Force Pore-Flow Model	105
6.1 Introduction	105
6.2 The Simulation Scheme	108
6.3 Results and Discussions	115
6.4 Conclusion	118
REFERENCES	120