

CONTENTS

ABBREVIATIONS.....	ix
SYMBOLS.....	x
1 Introduction.....	1
1.1 Industrial effluents.....	1
1.2 Industrial effluent treatment processes.....	1
1.3 Membrane bioreactors.....	4
1.3.1 The MBR technology.....	4
1.3.2 MBR drivers.....	4
1.3.3 MBR barriers.....	5
References.....	6
2 MBR design and operation fundamentals.....	7
2.1 Introduction.....	7
2.2 Membrane terms and materials.....	8
2.3 Design.....	9
2.3.1 Membrane configurations.....	9
2.3.2 Membrane separation process configurations.....	11
2.3.3 Biotreatment process configurations.....	12
2.3.4 Anaerobic MBRs.....	13
2.3.5 Aeration.....	14
2.4 Operation and maintenance (O&M).....	17
2.4.1 Membrane O&M.....	17
2.4.2 Biological process O&M.....	19
2.5 Ancillary equipment.....	20
2.6 Applications.....	20
2.7 Optimisation and costs.....	21
2.7.1 Capital expenditure (CAPEX).....	22
2.7.2 Operating expenditure (OPEX).....	24
2.7.3 Total cost.....	29
References.....	30
3 Industrial effluent quality and treatment.....	32
3.1 Industrial vs. municipal effluent treatment.....	32
3.2 Food and beverage.....	33
3.2.1 Fermentation industries.....	34
3.2.2 Dairy industries.....	37
3.2.3 Carbonated soft drinks and juice beverages.....	37
3.2.4 Cereals and snack foods.....	38
3.2.5 Potato and starch industry.....	39
3.2.6 Salads and vegetable products.....	39
3.2.7 Confectionery.....	40
3.2.8 Edible oils and spreads.....	41
3.2.9 Meat and poultry processing.....	42
3.3 Petroleum industry effluent.....	43
3.3.1 Exploration wastewater.....	43
3.3.2 Refinery wastewaters.....	44
3.4 Pharmaceutical wastewaters.....	48
3.4.1 Pharmaceuticals in the environment.....	48
3.4.2 Pharmaceutical industrial activities and effluent quality.....	49
3.4.3 Wastewater treatment.....	50
3.5 Pulp and paper industry.....	50
3.5.1 Pulp and paper processing.....	51
3.5.2 Water quality and treatment.....	52
3.5.3 MBRs in the P&P industry.....	54
3.6 Textile industry effluent.....	55
3.7 Landfill leachate.....	58
3.7.1 Leachate characteristics.....	58
3.7.2 Conventional landfill leachate treatment.....	58
3.7.3 Landfill leachate treatment using MBRs.....	59
3.8 Ship effluents.....	61
3.8.1 Legislation.....	61
3.8.2 Wastewater management and characteristics.....	63
3.8.3 Wastewater treatment technologies.....	64
3.8.4 Outlook, ship effluent treatment.....	65
3.9 Summary.....	65
References.....	67

4	MBR technologies.....	74
4.1	Immersed flat sheet (FS) products.....	75
4.1.1	Alfa Laval.....	75
4.1.2	Benenv.....	75
4.1.3	Brightwater/Anua.....	76
4.1.4	Ceraflo.....	77
4.1.5	Ecologix.....	77
4.1.6	Huber.....	78
4.1.7	ItN.....	78
4.1.8	KorED.....	79
4.1.9	Kubota.....	80
4.1.10	Lantian Peier.....	82
4.1.11	LiqTech.....	82
4.1.12	Martin.....	82
4.1.13	MaxFlow / A3.....	82
4.1.14	MegaVision.....	83
4.1.15	Meiden.....	83
4.1.16	MICRODYN-NADIR.....	84
4.1.17	newterra.....	85
4.1.18	Pure Envitech.....	85
4.1.19	QUA.....	85
4.1.20	SINAP.....	85
4.1.21	Supratec.....	87
4.1.22	Toray.....	87
4.1.23	FS product summary.....	88
4.1.24	FS technology suppliers.....	89
4.2	Immersed hollow fibre (HF) products.....	90
4.2.1	Asahi Kasei.....	90
4.2.2	Econity.....	90
4.2.3	Evoqua.....	91
4.2.4	GE.....	92
4.2.5	Hinada.....	92
4.2.6	Hyflux.....	92
4.2.7	Koch Membrane Systems.....	93
4.2.8	Kolon.....	93
4.2.9	Litree.....	94
4.2.10	Hangzhou Microna Membrane Technology Co. Ltd.....	94
4.2.11	Memstar/United Envirotech.....	94
4.2.12	Mitsubishi Rayon.....	95
4.2.13	Mohua.....	96
4.2.14	Motian.....	96
4.2.15	MOTIMO.....	96
4.2.16	Philos.....	97
4.2.17	Sumitomo.....	97
4.2.18	Superstring.....	98
4.2.19	Zena.....	98
4.2.20	HF product summary.....	98
4.3	Sidestream multi-tube (MT) and multi-channel (MC) modules.....	99
4.3.1	Polymeric MT membranes.....	99
4.3.2	Ceramic products.....	101
4.3.3	sMBR technology suppliers.....	102
4.3.4	Anaerobic sMBRs.....	104
4.4	Other products and technologies.....	104
4.4.1	Products from China.....	104
4.4.2	Other emerging technologies.....	105
4.5	Appraisal.....	105
	References.....	108
5	Case studies.....	109
5.1	Food and beverage.....	110
5.1.1	Canada Malting, Calgary, Canada.....	110
5.1.2	Holland Malt, Eemshaven, the Netherlands.....	111
5.1.3	Obolon maltery, Ukraine.....	111
5.1.4	Polar brewery, Caracas, Venezuela.....	112
5.1.5	Shepherd Neame Brewery, Faversham, UK.....	113
5.1.6	Arla Foods, Vimmerby, Sweden.....	113
5.1.7	Basic American Foods, Blackfoot, US.....	114

5.1.8	KMC, Brande, Denmark.....	115
5.1.9	Novidon, Belgium.....	116
5.1.10	Brodheads ville, PA.....	116
5.1.11	Food factory, Machida, Japan.....	117
5.1.12	Food processing plant, Taipei, Taiwan.....	118
5.1.13	Kanes Foods, Evesham, UK.....	118
5.1.14	Esmeralda, meat processing, Lima, Peru.....	119
5.1.15	Coosur, Jaén, Spain.....	120
5.1.16	Chicken slaughterhouse, Bona Avis, Ianca, Braila district, Romania.....	120
5.1.17	Arla Dairy, Aylesbury, UK (anaerobic MBR).....	121
5.1.18	Potato processing wastewater and tequila stillage pilot trials, anaerobic MBR.....	122
5.2	Petroleum and heavy industries.....	122
5.2.1	Sinopec Guangzhou, China.....	122
5.2.2	Formosa, Yunlin, Taiwan.....	124
5.2.3	Syndial, Porto Marghera, Italy.....	124
5.2.4	Petrochemical plant, Sichuan, China.....	125
5.2.5	Yanan Fengfuchuan oilfield reservoir, China.....	126
5.2.6	Baosteel Shanghai, China.....	127
5.2.7	Sinopec Luoyang, Henan Province.....	127
5.2.8	Intel, Qiryat Gat, Israel.....	129
5.2.9	Bromide plant, Israel.....	129
5.3	Pharmaceutical.....	130
5.3.1	Cosmetics effluent treatment, Madrid, Spain.....	130
5.3.2	Amgen, Puerto Rico.....	130
5.3.3	Sanofi Pasteur, Swiftwater, Pennsylvania, US.....	131
5.3.4	Pharmaceutical plant, Taizhou, Zhejiang Province, China.....	132
5.3.5	Pharmaceutical plant, Spain.....	132
5.3.6	Southern Taiwan Science Park (STSP) pilot plant, Chia Nan University, Taiwan.....	133
5.4	Pulp and paper.....	134
5.4.1	Gippsland Water Factory, Australia.....	134
5.4.2	Pulp and paper plant, Arizona, US.....	135
5.4.3	Paper mill, Gomà-Camps SAU, Spain.....	136
5.5	Textile.....	137
5.5.1	Bamberger Kaliko, Bamberg, Germany.....	137
5.5.2	Jiangsu Shenghong Printing & Dyeing Co., Ltd, China.....	138
5.5.3	Textil-Service Klingelmeyer, Darmstadt, Germany.....	139
5.5.4	Vanitec, Chennai, India.....	140
5.6	Landfill leachate.....	140
5.6.1	Songjiang District landfill site, JIMAO waste treatment company.....	140
5.6.2	Ecopark De Wierde, Omrin, the Netherlands.....	141
5.6.3	Da Phuoc landfill site, Ho Chi Minh City, Vietnam.....	142
5.6.4	Riederberg landfill site, Austria.....	143
5.6.5	Hazardous waste landfill site, Michigan, US.....	143
5.7	Ships.....	144
5.7.1	Ship effluent treatment, RWO Marine Water Technology.....	144
5.7.2	Ship effluent treatment, Wartsila.....	146
5.7.3	Ship effluent treatment, ROCHEM/ULTURA.....	147
5.8	Mixed industrial/municipal wastewater.....	148
5.8.1	Dalsung, South Korea.....	148
5.8.2	Taixin Binjiang WwTW, China.....	148
5.8.3	Tongjiang WwTW, Heilongjiang province, China.....	149
5.9	Appraisal.....	150
5.9.1	Aerobic.....	150
5.9.2	Anaerobic.....	152
5.9.3	General.....	152
	References.....	153
Annex 1	MBR operational energy and cost calculations.....	154
A	Process biology.....	154
B	Immersed membrane.....	155
C	Pumped sidestream membrane.....	155
Annex 2	Common conversions.....	157
INDEX.....		158