

Contents

Foreword	ix
Contributors	xi
Chapter 1	
<i>Aerobic granular biomass processes</i>	1
1.1 Background	1
1.1.1 Formation and morphology of aerobic granular sludge	2
1.1.2 Modelling of aerobic granular sludge	3
1.1.3 Aerobic granular sludge in practice	4
1.2 Laboratory scale experiments	4
1.2.1 Introduction	4
1.2.2 Objectives	5
1.2.3 Method description & lab scale reactor setup	6
1.2.4 Analytical methods	7
1.2.5 Results	9
1.3 NEREDA treatment of food industry wastewater	33
1.3.1 Introduction	33
1.3.2 NEREDA treating brewery wastewater	33
1.3.3 NEREDA treating food industry wastewater	36
1.4 Unifed treatment of abattoir wastewater	38
1.4.1 Introduction	38
1.4.2 Laboratory-scale experiences	38
1.4.3 Pilot-scale experiences – plant design	41
1.4.4 Pilot-scale experiences – results	43
1.4.5 Results of pilot-scale experiences	57
1.4.6 Conclusions	63
1.5 SBBGR treatment of landfill leachates	64
1.5.1 Introduction	64
1.5.2 Materials and methods	65
1.5.3 Results	71
1.5.4 Conclusions	85
References	86

Chapter 2

***Integrated processes* 91**

2.1 Background 91

2.2 Recalcitrant wastewater treatment by integrating solar advanced oxidation processes and immobilised biomass reactor 94

 2.2.1 Introduction 94

 2.2.2 Wastewater containing inhibiting/toxic compounds (pesticides) 98

 2.2.3 Wastewater containing a large amount of biodegradable organic compounds in addition to small concentrations of recalcitrant compounds (pharmaceuticals) 105

 2.2.4 Conclusions 112

2.3 Fundamental studies on immobilized photo fenton catalyst 112

 2.3.1 Introduction 112

 2.3.2 Optimisation of photocatalyst preparation and lab scale experiments 113

 2.3.3 Applications: adaptation to compound parabolic collector photoreactors 122

 2.3.4 Photocatalytic degradation of compound mixtures 127

 2.3.5 Conclusions 130

2.4 MBR/AOP treatment of pharmaceutical wastewater 130

 2.4.1 Introduction 130

 2.4.2 Preliminary investigations 131

 2.4.3 Laboratory scale studies 135

 2.4.4 Conclusions 146

2.5 Biozo treatment of landfill leachate 147

 2.5.1 Introduction 147

 2.5.2 Materials and methods 149

 2.5.3 Analytical methods 151

 2.5.4 Results 152

 2.5.5 Combining biological wastewater treatment with controlled ozonation – the BIOZO system 166

 2.5.6 Conclusions 171

References 172

Chapter 3

***Membrane-based processes* 179**

3.1 Background 179

3.2 Recovery of phenolic compounds with membrane contactors 180

 3.2.1 Introduction 180

 3.2.2 Membrane performance 181

 3.2.3 Membrane contactor modules 182

 3.2.4 Flow in spacer-filled channels 184

 3.2.5 Mass transfer investigations inside spiral wound modules 189

 3.2.6 Mass transfer investigations inside spiral wound modules 191

 3.2.7 Conclusions 192

3.3 Membrane chemical reactor design 193

 3.3.1 Introduction 193

 3.3.2 Description of the technology 195

 3.3.3 Factors influencing design: results 197

 3.3.4 Conclusions 209

References 211

Chapter 4

***Tailoring and assessment of wastewater treatment processes* 213**

4.1 Background 213

4.2 Methodology 214

 4.2.1 Specific objectives 214

 4.2.2 General approach 214

 4.2.3 Data and software requirements 215

4.2.4	Environmental assessment methodology	216
4.2.5	Economic assessment	219
4.2.6	Assessment strategy	219
4.3	Food industry wastewater	220
4.3.1	The assessed treatment case	220
4.3.2	Results of the assessment	226
4.3.3	Conclusions of the assessment of the food wastewater treatment	231
4.3.4	Uncertainties	231
4.4	Landfill Leachate	232
4.4.1	The assessed treatment case	232
4.4.2	Results of the environmental assessment	237
4.4.3	Economic assessment	242
4.4.4	Uncertainties	246
4.4.5	Conclusions	246
4.5	Pharmaceutical industry wastewater – the standard treatment case	247
4.5.1	Properties of nalidixic acid	247
4.5.2	Mathematically modelled treatments – photo-fenton + IBR and membrane contactor + IBR	248
4.5.3	Treatment by the reference technology and by the membrane bioreactor + ozonation (MBR + AOP)	251
4.5.4	Result of the environmental assessment	252
4.5.5	Economic assessment	254
4.5.6	Conclusion	256
References	256
Appendix 1	258
Appendix 2	259
Appendix 3	266