

Table of contents

Acknowledgment	VII
Abstract	IX
Kurzfassung	XI
List of figures	XVII
List of tables	XXI
Abbreviations and symbols.....	XXIII
1 Introduction.....	1
2 Objective of this work.....	4
3 Theoretical background	6
3.1 Particle synthesis and functionalization.....	6
3.1.1 Emulsion polymerization.....	6
3.1.2 Miniemulsion polymerization.....	7
3.1.3 Thiol-ene reaction for polymer functionalization.....	8
3.2 Membranes.....	10
3.2.1 Membrane processes for water treatment	10
3.2.2 Polymer membranes via phase separation.....	13
3.3 Fundamentals of adsorption.....	15
3.3.1 Principles of adsorption and ion-exchange.....	15
3.3.2 Adsorption isotherm models.....	18
4 State of the art.....	20
4.1 Mixed-matrix membranes.....	20
4.2 Membrane adsorbers.....	21
4.2.1 Mixed-matrix membrane adsorbers for target MPs.....	22
5 Experimental.....	26

5.1	Synthesis of porous polymer particles.....	26
5.1.1	PDVB particles by miniemulsion polymerization.....	26
5.1.2	Amination of PDVB particles via thiol-ene reaction.....	26
5.1.2.1	Methylation of aminated PDVB particles	27
5.1.2.2	EDTA functionalization of aminated PDVB particles	27
5.1.3	Carboxylation of PDVB particles via thiol-ene coupling.....	28
5.1.4	Sulfonation of PDVB particles via thiol-ene reaction.....	28
5.2	Syntheses of nonporous polymer particles	28
5.2.1	P(<i>St-co-DVB-co-VBC</i>) particles by emulsion polymerization.....	28
5.2.2	Amination of P(<i>St-co-DVB-co-VBC</i>) particles	29
5.2.3	Surface modification of P(<i>St-co-DVB-co-VBC</i>) with IDA	29
5.3	Preparation of hollow fiber membranes via phase separation.....	29
5.3.1	PVDF-based membrane adsorbers	29
5.3.2	PSU-based membrane adsorbers	31
5.4	Characterization methods of particles and membranes	32
5.4.1	Particle size, zeta potential and particle swelling.....	32
5.4.2	Elemental analysis (EA).....	33
5.4.3	Morphology	33
5.4.4	Specific BET surface area	33
5.4.5	Determination of the membrane geometry	34
5.4.6	Determination of the membrane pore sizes	34
5.4.7	Determination of the mechanical characteristics.....	34
5.4.8	Nitrogen and water permeance measurements	35
5.5	Adsorption experiments.....	35
5.5.1	Static adsorption experiments.....	35
5.5.1.1	Adsorption isotherms.....	37
5.5.2	Dynamic adsorption experiments	38
5.5.2.1	Regeneration.....	39
5.6	Analytical methods for the quantification of pollutants	39
6	Results and discussion.....	40

6.1 Properties of polymer particles	40
6.1.1 Particles morphology	40
6.1.2 Composition of the particles	48
6.1.3 Zeta potential of the particles.....	52
6.1.4 Degree of particle swelling.....	55
6.2 Adsorption properties of the particles.....	56
6.2.1 Adsorption behavior for micropollutants.....	56
6.2.1.1 Adsorption isotherms for micropollutants	61
6.2.2 Heavy metal adsorption	69
6.3 Summary of particle properties.....	73
6.4 Characterization of PVDF-based membrane adsorbers.....	75
6.4.1 Morphology and composition of the membrane adsorbers	75
6.4.2 Pore sizes of the membrane adsorbers.....	80
6.4.3 Mechanical characteristics of membrane adsorbers	82
6.4.4 Nitrogen and water permeance	83
6.5 Adsorption and desorption properties of PVDF-based membrane adsorbers...	85
6.5.1 Static micropollutant adsorption of the membrane adsorbers	85
6.5.2 Dynamic adsorption of the membrane adsorbers	87
6.5.3 Regeneration of the membrane adsorbers.....	94
6.6 Characteristics and adsorption properties of PSU-based membrane adsorbers	97
6.6.1 Morphology and pore sizes of PSU membrane adsorbers.....	97
6.6.2 Nitrogen and water permeance for PSU membrane adsorbers	100
6.6.3 Adsorption properties of the PSU membrane adsorbers.....	100
6.7 Summary of the membrane adsorber properties	103
7 Conclusions and outlook	105
References.....	108
Appendix.....	119
A.1 Materials	119
A.2 Particle characteristics	121

A.3 MP characteristics and tap water composition	122
A.4 Adsorption isotherms.....	123
A.5 Membrane adsorption.....	133
Curriculum vitae	135
Publications and conferences	137