

# Contents

<b>Zusammenfassung</b>	i
<b>Summary</b>	v
<b>Contents</b>	ix
<b>List of Tables</b>	xiii
<b>List of Figures</b>	xv
<b>List of Abbreviations</b>	xix
<b>1. Introduction</b>	1
1.1. Drinking water production using natural cleaning systems . . . . .	1
1.2. AGR site Lange Erlen . . . . .	3
1.2.1. Aquifer and groundwater . . . . .	4
1.2.2. Soils and vegetation . . . . .	4
1.2.3. Drinking water production . . . . .	5
1.3. Pollution of surface waters - a hazard for drinking water production . . . . .	6
1.4. Efficiency of natural cleaning systems . . . . .	10
1.4.1. Biodegradation and impact of redox milieu . . . . .	10
1.4.2. Temperature . . . . .	12
1.4.3. Sorption . . . . .	12
1.4.4. Contribution of subsoil horizons . . . . .	13
1.4.5. The role of dissolved organic carbon . . . . .	13
1.5. Objective of this study . . . . .	15
<b>2. Gas sampling in a partly saturated soil in an artificial groundwater recharge site</b>	17
2.1. Abstract . . . . .	17
2.2. Introduction . . . . .	17
2.3. Material and Methods . . . . .	19
2.3.1. Sampled sites . . . . .	19
2.3.2. Installation of gas sampling systems and sampling . . . . .	19
2.3.3. Gas analysis . . . . .	21
2.3.4. Data analysis . . . . .	22
2.4. Results and Discussion . . . . .	22
2.4.1. CO <sub>2</sub> , N <sub>2</sub> O and δ <sup>13</sup> C - extraction of gas only . . . . .	24
2.4.2. CO <sub>2</sub> , N <sub>2</sub> O and δ <sup>13</sup> C - simultaneous extraction of gas and water . . . . .	24
2.4.3. Indifferent results for CH <sub>4</sub> . . . . .	26
2.4.4. Literature on subsurface gas sampling and the impact of water . . . . .	27
2.5. Conclusion . . . . .	28

<b>3. Self-cleaning vadose zone - the fate of dissolved organic carbon in an artificial groundwater recharge site</b>	<b>29</b>
3.1. Abstract . . . . .	29
3.2. Introduction . . . . .	30
3.2.1. The fate of DOC - a matter of concern? . . . . .	30
3.2.2. Dilution . . . . .	30
3.2.3. Sorption . . . . .	31
3.2.4. Degradation . . . . .	31
3.3. Material and Methods . . . . .	33
3.3.1. Sites investigated . . . . .	33
3.3.2. Sampling of water, solid and gas phase . . . . .	33
3.3.3. Preparation and analyses of water, solid and gas samples . . . . .	35
3.3.4. Definitions and calculations . . . . .	42
3.4. Results and Discussion . . . . .	46
3.4.1. Overall removal of DOC . . . . .	46
3.4.2. Dilution . . . . .	47
3.4.3. Removal of DOC by degradation and sorption . . . . .	54
3.4.4. Sorption onto the solid phase . . . . .	55
3.4.5. Degradation of DOC . . . . .	61
3.4.6. Spatial and temporal variation of subsurface gas phase composition	69
3.5. Conclusion . . . . .	79
<b>4. Removal of dissolved organic carbon (DOC) and organic trace pollutants in a column percolation experiment</b>	<b>83</b>
4.1. Abstract . . . . .	83
4.2. Introduction . . . . .	84
4.3. Material and Methods . . . . .	86
4.3.1. Bulk material for filling the columns . . . . .	86
4.3.2. Stainless steel columns – setup . . . . .	86
4.3.3. Column Percolation . . . . .	88
4.3.4. Time table of the percolation experiment and treatments . . . . .	88
4.3.5. Water sampling . . . . .	91
4.3.6. Water analytics . . . . .	92
4.3.7. Gas sampling . . . . .	93
4.3.8. Gas Analytics . . . . .	95
4.3.9. Automated sampling circuit and software . . . . .	96
4.3.10. Soil column hydraulic properties - break through curves . . . . .	96
4.3.11. Calculations and statistics . . . . .	97
4.4. Results and Discussion . . . . .	98
4.4.1. Hydraulic properties of soil columns: Breakthrough curves (BTC) of NaCl and estimation of retention time . . . . .	98
4.4.2. Test for sorption or release of anions and cations . . . . .	99
4.4.3. Experimental conditions and redox setting . . . . .	100
4.4.4. Removal of DOC . . . . .	108
4.4.5. Removal of organic trace pollutants . . . . .	115
4.5. Conclusion . . . . .	125
4.5.1. Removal efficiency and role of subsoil horizons . . . . .	125
4.5.2. Priming effects of saccharose . . . . .	126

4.5.3. Scenarios with pollution of the Rhine . . . . .	127
4.5.4. Column experiments - a useful tool . . . . .	128
<b>5. Co-Regulation of redox processes in freshwater wetlands as a function of organic matter availability?</b>	<b>129</b>
5.1. Abstract . . . . .	129
5.2. Introduction . . . . .	130
5.3. Methods and Sites . . . . .	131
5.3.1. Site descriptions . . . . .	131
5.3.2. Methods . . . . .	131
5.4. Results and Discussion . . . . .	134
5.4.1. Redox processes under high DOC regime: Results from the Lehstenbach catchment . . . . .	134
5.4.2. Redox processes under low DOC regime: Results from Lange Erlen . . . . .	137
5.5. Conclusion . . . . .	140
5.6. Acknowledgements . . . . .	140
<b>6. Concluding Discussion and Outlook</b>	<b>141</b>
6.1. Cleaning efficiency of AGR site Lange Erlen . . . . .	141
6.1.1. Processes contributing to the removal of DOC and trace pollutants . . . . .	141
6.1.2. Parameters impairing or enhancing the cleaning efficiency of the AGR system . . . . .	142
6.2. Comparison of conventional and natural treatment . . . . .	147
6.3. Future developments . . . . .	147
6.4. Outlook . . . . .	148
<b>Bibliography</b>	<b>151</b>
<b>A. Appendix</b>	<b>175</b>
<b>Acknowledgements</b>	<b>179</b>