

**On possibilities of the post-treatment of anaerobic digester effluents  
with high H<sub>2</sub>S loads in constructed wetlands**

**Dissertation**

zur Erlangung des akademischen Grades

Doktoringenieur (Dr. -Ing.)

vorgelegt dem

Zentrum für Ingenieurwissenschaften

der Martin-Luther-Universität Halle-Wittenberg

als organisatorische Grundeinheit für Forschung und Lehre im Range einer Fakultät

(§75 Abs. 1 HSG LSA, §19 Abs. 1 Grundordnung.)

von

Alvaro Enrique Gonzalias Mosquera

geboren am 31. August 1968 in Kolumbien

Verteidigung am 06.02.2008

Gutachter: Prof. Dr.-Ing. H. Köser.

Prof. Dr. Walter

Halle/Saale, 18. Februar 2008

**urn:nbn:de:gbv:3-000013114**

[<http://nbn-resolving.de/urn/resolver.pl?urn=nbn%3Ade%3Agbv%3A3-000013114>]

## CONTENTS

1	Introduction .....	1
1.1	Objectives .....	4
1.2	Problem.....	4
2	Literature Review.....	6
2.1	Chemical methods for H <sub>2</sub> S removal in wastewaters .....	6
2.2	Biological Methods .....	8
2.2.1	Biological sulphur cycle.....	8
2.2.2	Sulphate reduction .....	11
2.2.3	Oxidation of reduced sulphur species .....	12
2.2.4	Microorganisms of particular interest for Sulphur removal.....	13
2.2.5	Ponds.....	16
2.2.6	Constructed Wetlands .....	18
3	Material and Methods .....	54
3.1	Characterization of sulphide toxicity to <i>Juncus effusus</i> .....	54
3.1.1	Plant material.....	54
3.1.2	Experimental set-up .....	54
3.1.3	Measurements of plant related parameters.....	55
3.2	Treatment of sulphide containing model wastewater in the Planted Fixed Bed Reactor.....	57
3.2.1	Synthetic wastewater .....	57
3.2.2	Laboratory-scale reactor .....	60
3.2.3	Plants biomass .....	62
3.2.4	Experimental conditions .....	62
3.2.5	Sampling .....	63
3.3	Treatment of a sulphide containing model wastewater in the Laboratory-scale Horizontal Subsurface Flow Wetland .....	64
3.3.1	Synthetic wastewater .....	64
3.3.2	Laboratory-scale reactor .....	64
3.3.3	Experimental conditions .....	66
3.3.4	Sampling .....	68
3.4	Analytical methods.....	68

3.4.1	Dissolved sulphide.....	68
3.4.2	Sulphite and thiosulphate.....	68
3.4.3	Elemental sulphur.....	69
3.4.4	Total carbon and total organic carbon.....	69
3.4.5	Ion chromatography analysis (IC).....	69
3.5	Other parameters.....	70
3.5.1	Redox potential (Eh) and pH measurement.....	70
3.5.2	Evapotranspiration.....	70
3.5.3	Shoot density.....	71
3.5.4	Gravel analysis.....	71
3.5.5	Total sulphur.....	72
3.5.6	Total nitrogen.....	72
3.5.7	Specific removal rate.....	72
3.5.8	Data analysis.....	72
4	Results and discussions.....	73
4.1	Characterization of sulphide toxicity to <i>J. effusus</i> .....	73
4.2	Treatment of a model wastewater in the Planted Fixed Bed Reactor -PFBR.....	78
4.2.1	Dynamics of S-species.....	78
4.2.2	Sulphur balances calculations.....	81
4.2.3	Nitrogen species /removal.....	83
4.2.4	Carbon removal.....	85
4.2.5	Further parameters (shoot density, EVT, Eh and pH).....	86
4.2.6	Statistical evaluation.....	89
4.2.7	Specific removal rate of sulphur species in the PFBR.....	91
4.2.8	Conclusions.....	93
4.3	Treatment of artificial sulphide containing wastewater in subsurface horizontal flow laboratory-scale constructed wetlands.....	95
4.3.1	Dynamics of S-species.....	95
4.3.2	Sulphur balance calculation.....	99
4.3.3	Sulphur loading and removal rates.....	101
4.3.4	Nitrogen species / removal.....	104
4.3.5	Carbon removal.....	108
4.3.6	Further parameters (shoot density, EVT, Eh and pH).....	109
4.3.7	Statistical evaluation.....	112
4.3.8	Specific removal rate of sulphur species in subsurface horizontal flow laboratory-scale constructed wetlands.....	114
4.3.9	Conclusions.....	116
5	Summary and Conclusions.....	118

6	References .....	123
7	Appendix .....	151

## **Acknowledgements**

I would like to express my most sincere gratitude to Prof. Dr. Heinz Köser for his generous support and encouragement throughout my study and to Dr. Peter Kuschik for his support and for his invaluable suggestions and advice during my work at the Department of Bioremediation, Helmholtz Centre for Environmental Research – UFZ Leipzig.

I would also like to express my grateful thanks to Dr. Manfred Jank for his help and suggestions throughout my experimental studies.

I gratefully acknowledge the KAAD Catholic Academic Exchange Service for the financial grant and incentive support to this study, and also thank to the Universidad Pontificia Bolivariana Bucaramanga-Colombia for giving me a chance to progress my study in Germany. Without this kind support, this study would not have been possible.

I am also grateful to my colleagues, Mrs. Kerstin Puschendorf and Mrs. Ines Mäusezahl, Department of Bioremediation for their great help and suggestions concerning the chemical-analytical technique. My sincere thanks to Mr. Reinhard Schumann for his help and support in the field test experiment. I want to thank specially Prof. Dr. Matthias Kästner, Dr. Arndt Wiessner and M.Sc. Diego Paredes for their suggestions and support.

Special thanks to all my colleagues of UFZ for their helps and support during my working period and for making me feels at home. Thanks are due to M.Sc. Imfeld Gwenael for statistical assistance and to Maria Kuschik for improving the English of this thesis.

There are no words to adequately describe the feelings of gratitude for my family and friends, their continuous support and encouragement throughout my study. Special thank to Dr. Diana Ma. Agudelo V., for gave me personal advice and great encourage. Thanks are due to Mrs. Eva and Mr. Haiko Kutzscher for giving me a special place in their family during my stay in Leipzig.

Finally but not less I want to express sincere thank to Mr. Carsten Richter for his great and kind support.