

**Nitrogen Transformation Pathways and Removal Mechanisms in
Domestic Wastewater Treatment by Maturation Ponds**

by

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Submitted in accordance with the requirements of the degree of
Doctor of Philosophy

The University of Leeds
School of Civil Engineering

September, 2008

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Acknowledgements

I would like to express my sincere thanks to Professor Duncan Mara for believing in my potential as a researcher and for giving to me the unique opportunity to become a member of his leading research group on sanitation at the School of Civil Engineering, the University of Leeds. During my PhD studies, his supervision, reviews and guidance made a significant contribution to my personal and academic development; particularly his permanent support encouraging me to communicate my research findings to international peers at the highest academic level. Without his support and advice, this thesis could not have been produced the way it is.

I also wish to express my appreciation and gratitude to the technical staff of the School of Civil Engineering, particularly to Mr Keith Pierre, Mr Mick China, Mrs Karen Stevens and Mr Steve Holmes. Thanks you all for your assistance with my laboratory work and for making the public health laboratory a nice place to work in, even during my almost endless laboratory sessions. I am also thankful to my fellow PhD students, especially to my friends Michelle Johnson, Elly van der Linde, Chimwemwe Banda, Aby Hathway, Kat Roberts and Shanmugam Palani, who were always there when the laboratory and field work were difficult and demanding and also made me feel at home during my days in our office – Room G-13 gave me memorable moments that I will keep with me for ever.

Thank you to our research partners at the School of Earth and Environment, the University of Leeds, Professor Simon Bottrell for his expert advice and guidance on planning tracer experiments with stable nitrogen isotopes, and Dr Rob Newton for training and support on my ^{15}N analyses. I would like also to thank Mrs Fiona Read and Dr Russell Davenport, School of Civil Engineering and Geosciences, University of Newcastle Upon Tyne, for their invaluable help with the molecular microbiology work.

I gratefully acknowledge the financial support given by the National University of Colombia, COLFUTURO, the Engineering and Physical Sciences Research Council and the School of Civil Engineering, University of Leeds; and especially to Yorkshire Water who also generously provided the site and give me almost day-to-day operational support in one way or another at Esholt.

Abstract

The mechanisms and pathways by which nitrogen in its various forms is removed from waste stabilisation ponds (WSP) have been a subject of much debate for wastewater scientists and engineers. Nitrogen removal in WSP has been attributed to ammonia volatilisation and sedimentation of organic nitrogen via biological uptake. However, researchers have found it difficult to determine whether sedimentation or volatilisation is the dominant mechanism for nitrogen removal because of the very complex interactions in the biochemical pathways involved, although it was thought that volatilisation may dominate during the warm summer months and deposition during the winter. In order to improve current understanding of the dynamics of inorganic and organic nitrogen removal in WSP systems, a study was undertaken on an experimental pilot-scale WSP system at Esholt Wastewater Treatment Works (Bradford, UK) which includes a classical monitoring performance over the experimental timeframe and tracer experiments with stable nitrogen isotopes (^{15}N) in summer and winter. A primary maturation pond (M1) was spiked separately with ^{15}N -labelled ammonia ($^{15}\text{NH}_4\text{Cl}$), ^{15}N -labelled nitrite ($\text{Na}^{15}\text{NO}_2$) and ^{15}N -labelled algae (*Chlorella vulgaris*) to track nitrogen transformations and removals associated with ammonia volatilisation, nitrification, algal uptake and sedimentation of organic nitrogen. Stable isotope analysis of $\delta^{15}\text{N}$ showed that the nitrogen cycle in maturation ponds is dominated in summer by biological uptake as ammonium nitrogen is rapidly transformed into algal biomass as suspended organic nitrogen which then either leaves in the pond effluent or is sedimented as dead cells. Ammonia removal by volatilisation makes little or no contribution to nitrogen removal either in summer or winter. Classical nitrification is masked by biological nitrate uptake in summer and simultaneous denitrification in winter. Thus algal uptake of inorganic nitrogen (mainly ammonium) and subsequent sedimentation and retention in the sludge layer, after partial ammonification of the algal organic nitrogen in the sludge layer, appears to be the dominant mechanism for permanent nitrogen removal in maturation ponds during warm summer months. Ammonium nitrification and simultaneous denitrification may be the dominant mechanism of total nitrogen removal during the cold winter months in temperate climates.

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List of Acronyms and Abbreviations

ANAMMOX	Anaerobic ammonium oxidation process
BLAST	Basic local alignment search tool
BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
CEC	Council of the European Communities
Defra	Department for Environment Food and Rural Affairs
DGGE	Denaturing gradient gel electrophoresis
DO	Dissolved oxygen
EC	European Community
EMEP	Co-operative programme for monitoring and evaluation of long range transmission of air pollutants in Europe
EEC	European Economic Community
EU	European Union
FC	Faecal coliforms
IFA	International Fertilizer Industry Association
PCR	Polymerase chain reaction
p.e.	Population equivalent
PFP	Primary facultative pond(s)
RFA	Renewable Fuel Association
SFP	Secondary facultative pond(s)
SS	Suspended solids
TKN	Total Kjeldhal nitrogen
UNECE	United Nations Economic Commission for Europe
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNHSP	United Nations Human Settlements Programme
USA	United States of America
USEPA	United States Environmental Protection Agency
UK	United Kingdom
UWWTD	Urban waste water treatment directive
VFA	Volatile fatty acid(s)
WHO	World Health Organization
WSP	Waste stabilization pond(s)
WWTP	Wastewater treatment plant(s)