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

by

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The candidate confirms that the work submitted is his own and that appropriate credit has been given where reference has been made to the work of others.

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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 ($^{15}NH_4Cl$), ^{15}N-labelled nitrite ($Na^{15}NO_2$) 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 $\delta^{15}N$ 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 Heath Organization
WSP	Waste stabilization pond(s)
WWTP	Wastewater treatment plant(s)