Nitrogen Removal in a Foam Media Biofilter for On-site Wastewater Treatment Systems

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David Rei Miller

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Abstract

Discharges of nitrogen can contaminate groundwater, and cause algal blooms or eutrophication in surface waters. On-site wastewater treatment systems (OWTS) have been identified as significant sources of nitrogen. Homeowners and manufacturers are under increasing pressure to install OWTS capable of effective nitrogen removal.

Biological nitrogen removal in OWTS usually takes place in a fixed growth biofilter, following primary treatment in a septic tank arrangement. Three configurations of OWTS using foam media biofilters were assessed in the field. Foam media has advantages over sand, as high porosity and large air gaps allow the simultaneous flow of wastewater and air, thus reducing clogging and allowing higher loading rates.

Septic tank effluent had lower concentrations of TSS, COD and TN in configurations with larger tank volume. Biofilters provided additional removal of TSS and COD to give effluent concentrations as low as 9 mg/L and 36 mg/L respectively. TN concentration in the effluent varied from 41-53 mg/L depending on configuration. The least nitrogen removal occurred in the configuration with the highest loading rate (in terms of $L/m^2/d$).

A bench-scale biofilter constructed using a single foam block (200 x 160 x 60 mm) achieved TN removal up to 10.7 mg/L (0.024 g-N/d at a dosing rate of 2.2 L/d). It was observed that nitrification and denitrification can both occur in a single foam block. Assimilation was also a significant nitrogen removal mechanism, accounting for up to 49 % of total removal.

DO concentrations at microenvironments within the bench-scale biofilter were determined using a miniature membrane electrode. A syringe needle and custom-made plunger with the electrode fitted inside allowed DO concentration to be determined in sample volumes as small as 1 mL. The empirical equation derived to calculate DO concentration was accurate to within ± 2.9 %.

The extent of nitrification was greatest after an overnight rest period. At microenvironments within the bench-scale biofilter, nitrification increased at longer hydraulic residence time. Nitrification increased at high feed concentrations of carbon, which was not expected, and did not decrease at DO concentrations as low as 0.88 mg/L.

Denitrification was greatest when feed was high in carbon and low in DO, but was not affected by DO concentrations as high as 2.70 mg/L.

The effects of loading rate, biofilter depth, recirculation ratio and flooding need to be investigated further to optimise the design of biofilters in the field.

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Abbreviations

Amm-N	ammonia-nitrogen (NH_3/NH_4^+)
AOB	ammonia-oxidising bacteria
AS	activated sludge
AUF	anaerobic upflow filter
BNR	biological nitrogen removal
BOD	biological oxygen demand
BOD_5	biological oxygen demand (5 day)
COD	chemical oxygen demand
FISH	fluorescence *in situ* hybridisation
FSS	fixed suspended solids
HLR	hydraulic loading rate
HRT	hydraulic residence time
ISF	intermittent sand filter
LGA	local government authority
MABR	membrane aerated biofilm reactor
MBR	membrane biofilm reactor
N	nitrogen
Nit-N	nitrified nitrogen (NO_2^-/NO_3^-)
NOB	nitrite-oxidising bacteria
NTF	nitrifying trickling filter
OLR	organic loading rate
Org-N	organic nitrogen
OWTS	on-site wastewater treatment system
PPD	per person per day
PPY	per person per year
RSF	recirculating sand filter
SAF	soil absorption field
SND	simultaneous nitrification and denitrification
SS	suspended solids
STE	septic tank effluent
TKN	total Kjeldahl nitrogen (sum of Org-N and Amm-N)
TN	total nitrogen
TOC	total organic carbon
TSS	total suspended solids
VSS	volatile suspended solids
WWTP	wastewater treatment plant

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