

Nitrogen removal from urban wastewater by activated sludge process operated over the conventional carbon loading rate limit at low temperature

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Abstract

This study deals with nitrogen removal from urban wastewater employing the activated sludge process at low temperature. It aims at determining the performances and rates of nitrification, and characterising the autotrophic biomass (concentration and kinetic parameters) at 11°C and for F/M ratios higher than the conventional maximum value of 0.1 kg BOD₅·kg MLVSS⁻¹·d⁻¹ (i.e. SRT around 15 d).

To reach this objective, a study of a continuous activated sludge pilot plant operated under controlled conditions was undertaken for five months. Two methods were used:

- A combination of nitrogen mass balance on the continuous reactor and weekly tests in a separate batch reactor
- The use of the Activated Sludge Model No 1 (ASM₁) calibrated and validated with 6 intensive sampling test runs in the aeration tank of the pilot plant.

Once it had been demonstrated that it was not possible to predict the nitrogen concentrations with the ASM₁ default values recommended at 10°C, we modified 4 parameters to correctly simulate the 6 intensive sampling test runs: the autotrophic biomass maximum growth rate values ($\mu_{A, \max} = 0.22 \text{ d}^{-1}$ with a decay rate value of $b_A = 0.02 \text{ d}^{-1}$), as well as three of the half-saturation constants ($K_{\text{NH}} = 0.05 \text{ mg NH}_4\text{-N } \ell^{-1}$, $K_{\text{OH}} = 0.05 \text{ mg O}_2\text{-}\ell^{-1}$, and $K_s = 30 \text{ mg COD}\cdot\ell^{-1}$).

These modifications, implemented on the basis of more accurate predictions of nitrification and denitrification rates in the aeration tank, have reduced the errors of predictions for the main biological variables in the reactor and in the treated water. The sensitivity of the estimated parameter values to the accuracy of the initialisation conditions step has also been studied. It was shown that a mistake of underestimation of the sludge concentration by 6%, compared to the experimental value, has induced the overestimation of the maximum autotrophic growth rate by 7%.

Keywords: activated sludge; nitrification; reaction rates; kinetics parameters; modelling wastewater treatment plant

Nomenclature

ASM ₁	Activated Sludge Model No 1
b_A	autotrophic biomass decay rate (d ⁻¹)
$B_V(N)$	volumetric nitrogen load (mg N·ℓ ⁻¹ ·d ⁻¹)
D_{acr}	daily aeration time (h·d ⁻¹)
BOD ₅	biological oxygen demand (mg O ₂ ·ℓ ⁻¹)
COD	chemical oxygen demand (mg O ₂ ·ℓ ⁻¹)
DO	dissolved oxygen concentration (mg O ₂ ·ℓ ⁻¹)
f_{AT}	fraction of total sludge mass in the aeration tank (%)
F/M	organic carbon loading rate (kg BOD ₅ ·kg MLVSS ⁻¹ ·d ⁻¹)
K_{NH}	ammonia half-saturation coefficient for autotrophic biomass (mg N·ℓ ⁻¹)
K_{OH}	oxygen half-saturation coefficient for heterotrophic biomass (mg O ₂ ·ℓ ⁻¹)
K_s	readily biodegradable COD half-saturation coefficient (mg COD·ℓ ⁻¹)

$MX_{B,A}$	mass of autotrophic bacteria in the system (mg COD)
$[\text{NH}_4\text{-N}]_{\text{AT}}$	aeration tank ammonia nitrogen concentration (mg N·ℓ ⁻¹)
$[\text{NO}_x\text{-N}]_{\text{AT}}$	aeration tank nitrates + nitrites concentration (mg N·ℓ ⁻¹)
$[\text{NH}_4\text{-N}]_{\text{out}}$	output ammonia nitrogen concentration (mg N·ℓ ⁻¹)
$[\text{NO}_x\text{-N}]_{\text{out}}$	output nitrates + nitrites nitrogen concentration (mg N·ℓ ⁻¹)
P.E.	population equivalent (for 0.15 m ³ ·d ⁻¹ and 60 g BOD ₅ ·d ⁻¹)
rpm	rotations per minute (r·min ⁻¹)
$r_{v, \max \text{ nit}}$	maximum volumetric nitrification rate (mg NO _x -N·ℓ ⁻¹ ·h ⁻¹)
SE ([C])	sum of absolute values of the difference between simulated and measured concentrations (mg N·ℓ ⁻¹ ·point ⁻¹). n = Number of points
SRT	sludge retention time or sludge age (d)
S_i	soluble inert COD concentration (mg COD·ℓ ⁻¹)
S_s	soluble biodegradable COD concentration (mg COD·ℓ ⁻¹)
S_{ND}	soluble organic nitrogen concentration (mg N·ℓ ⁻¹)

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