CVEN 5534: Biological Wastewater Treatment
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Assignment # 3: (SOLUTIONS)

A wastewater treatment plant comprised of a simple one-tank CSTR with cell recycle activated sludge process was designed for removal of COD. The facility operators are considering upgrading the facility to achieve complete ammonia removal by nitrification. If possible they would like to maintain the aerated CSTR tank, pumps and piping of the current system. The plant influent has 200 mg/L COD and 35 mg/L ammonia as nitrogen (NH_4-N). The capacity of the plant's aeration system is 500 g/(m^3-d) O_2.

Operating characteristics and biokinetic constants are as follows:

Parameter	Value
HRT = τ	6 hours
SRT = θc	10 days
$\hat{\mu}_H$	5 d^{-1}
$\hat{\mu}_A$	1 d^{-1}
b [1]	0.1 d^{-1}
K_S	25 mg/L COD
K_N	4 mg/L NH_4-N
Y_H	0.6 g-cell COD/g-substrate COD
f	0.2 g-debris COD formed/g-biomass COD decayed
$i_{N/XT}$ [2]	0.087 g-N/g-biomass COD

[1] same for both heterotrophic and autotrophic bacteria
[2] same for both viable biomass and debris

Assume that rates for both COD oxidation and nitrification follow Monod kinetics and are substrate (electron donor) limited.

a) Can the plant achieve significant ammonia removal (> 95%) with current facilities and sludge wasting rate? (Show calculations)

a) yes if enough oxygen is supplied:

<u>COD (S_S):</u>

$$S_S = \frac{K_S(1+b\theta_C)}{\hat{\mu}_H\theta_C - (1+b\theta_C)} = 1\,mg/L\ COD$$

NH_4 (S_{NH})

$$S_{NH} = \frac{K_N(1+b\theta_C)}{\hat{\mu}_A\theta_C - (1+b\theta_C)} = 1\ \text{mg/L}\ NH_4 - N$$

99.5% COD removal and 97% ammonia removal for θ_C = 10 days, <u>if enough oxygen can be supplied.</u>

b) Calculate the oxygen requirement for simultaneous COD oxidation and nitrification. (You can neglect the yield of the <u>autotrophic</u> biomass.)

b) $$\mathbf{RO/V = r_S(1 - Y_{Hobs}) + 4.57(r_{NH} - i_{NX}Y_{Hobs}r_S)}$$

Where:
RO/V = rate of oxygen consumption (gO_2/m^3-d)
r_S = rate of COD removal = $(S_{SO}-S_S)/\tau$ ($gCOD/m^3$-d)
τ = V/Q (d)
Y_{Hobs} = observed yield = $(1+fb\theta_C)Y_H/(1+b\theta_C)$ (g-COD-cells/g-COD-substrate)
r_{NH} = rate of ammonia nitrification = $(S_{NHO}-S_{NH})/\tau$ (gNH_4-N/m^3-d)
4.57 g-COD/g-NH_4-N
and all other terms as define in problem statement

Since S_S = 1 g/m^3, S_{NH} = 1 g/m^3, τ = 0.25 d and θ_C = 10 d

Oxygen requirement for complete COD and ammonia removal:

$$\mathbf{RO/V = 509\ g/m^3\text{-}d^{(1)} + 508\ g/m^3\text{-}d^{(2)} \approx 1{,}000\ g\text{-}O_2/m^3\text{-}d}$$

$^{(1)}$ net oxygen consumption for COD substrate (minus fraction in X_{BH})
$^{(2)}$ net oxygen consumption for nitrification (minus fraction in X_{BH})

b) Will the plant need a new aeration system? Is a higher capacity aeration system feasible, given that limitations for conventional aeration equipment are 1,500 $g/(m^3$-d) O_2?

c) **YES plant will need new aeration system**. Requirement is twice the capacity of the old system. However, the new oxygen requirement is well within the capability of a conventional aeration system, so the current facility performance can be upgraded to include ammonia removal by nitrification relatively easily.