Solution: Exercise 1

Typical Concentrations of Nitrogen in Influent & Effluent

	Raw Municipal Influent	Primary Effluent	Secondary Effluent (No Nitrification)	Secondary Effluent (Nitrified)
NH_4^+- N	15	16	12	1.0
SKN	18	18	13	1.2
TKN	30	25	15	2.2
NO_2^-- N	0	0	0	0.1
NO_3^-- N	0	0	0	17
Total N	30	25	15	19.3
Sol. Organic - N	3	2	1	0.2
Organic - N	15	9	3	1.2

Calculation of Required Mean Cell Residence Time for Nitrification

Solution :Exercise 2

Required Input Data

(1) Average Temperature in Aeration Tank, T **20** °C

(2) Average Effluent Ammonia Concentration **1.0** mg/L (as N)

(3) Average Aeration Tank Dissolved Oxygen Concentration **3.0** mg/L

Determine Maximum Specific Growth Rate Corrected For Temperature ($\mu_{max,T}$)

(4) $$\mu_{max,\,T} = (0.65)(1.055)^{(T\ -\ 25)}$$

(5) $$\mu_{max,\_} = (0.65)(1.055)^{(20\ -\ 25)} = 0.497\ day^{-1}$$

Enter temperature in °C from line (1)

Determine Decay Rate Corrected For Temperature (k_d)

(6) $$k_d = (0.05)(1.055)^{(T\ -\ 25)}$$

(7) $$k_d = (0.05)(1.055)^{(20\ -\ 25)} = 0.038\ day^{-1}$$

Enter temperature in °C from line (1)

Determine Growth Rate Correction Factor For Ammonia Concentration

(8) $$CF_{NH_4^+} = \frac{NH_4^+ \text{-} N}{K_N + NH_4^+ \text{-} N}$$

(9) $$K_N = (1.0)(1.055)^{(T\text{-}25)}$$

(10) $$K_N = (1.0)(1.055)^{(20 - 25)} = 0.765 \text{ mg / L}$$

Enter temperature in °C from line (1)

(11) $$CF_{NH_4^+} = \frac{1.0}{0.765 + 1.0} = 0.567$$

Enter K_N from line (10)

Enter effluent ammonia from line (2)

Determine Growth Rate Correction Factor For Dissolved Oxygen Concentration

(12) $$CF_{DO} = \frac{DO}{1 + DO}$$

(13) $$CF_{DO} = \frac{3.0}{1 + 3.0} = 0.75$$

Enter DO from line (3)

Determine Growth Rate Corrected For Temperature, Ammonia and DO

(14) $$\mu_T = \mu_{max,\,T}\,(CF_{NH_4^+})(CF_{DO})$$

(15) $$\mu_T = (0.497)(0.567)(0.75) = 0.211\ \text{day}^{-1}$$

Enter CF_{DO} from line (13)

Enter CF_{NH4+} from line (11)

Enter $\mu_{max,T}$ from line (5)

Determine Required MCRT

(16) $$MCRT = \frac{1}{\mu_T - k_d}$$

(17) $$MCRT = \frac{1}{0.211 - 0.038} = 5.77\ \text{days}$$

Enter k_d from line (7)

Enter μ_T from line (15)

Calculation of Actual Mean Cell Residence Time

Solution: Exercise 3

Required Input Data

Aeration Tank Volume

(1)	Aerobic Volume , V_{AER}	**7.5**	MGal
(2)	Anoxic Volume (if applicable), V_{ANOX}	**2.5**	MGal

Average MLSS Concentration

(3)	Aerobic Zone, MLSS	**2500**	mg/L
(4)	Anoxic Zone (if applicable), $MLSS_{ANOX}$	**2500**	mg/L
(5)	Sludge Wasting Rate, Q_W	**0.5**	MGD
(6)	Waste Sludge Solids Concentration, TSS_W	**7500**	mg/L TSS
(7)	Clarifier Effluent Flow, Q_E (Plant Flow)	**40**	MGD
(8)	Clarifier Effluent TSS, TSS_E	**13**	mg/L

Determine Mass of Solids in Anoxic Zone

(9) $M_{ANOX} = (V_{ANOX})(8.34)(MLSS_{ANOX})$

(10) $M_{ANOX} = (2.5)(8.34)(2500) = 52{,}125 \text{ lb}$

Enter from line (2)

Enter from line (4)

Determine Mass of Solids in Aerobic Zone

(11) $M_{AER} = (V_{AER})(8.34)(MLSS_{AER})$

(12) $M_{AER} = (7.5)(8.34)(2500) = 156{,}375$ lb

Enter from line (1) Enter from line (3)

Determine Mass of Solids Removed from System in Waste Sudge

(13) $M_W = (Q_W)(8.34)(TSS_W)$

(14) $M_W = (0.5)(8.34)(7{,}500) = 31{,}275$ lb/day

Enter from line (5) Enter from line (6)

Determine Mass of Solids Removed from System in Plant Effluent

(15) $M_E = (Q_E)(8.34)(TSS_E)$

(16) $M_E = (40)(8.34)(13) = 4{,}337$ lb/day

Enter from line (7) Enter from line (8)

Determine Overall MCRT

(17) $MCRT = \frac{(M_{ANOX} + M_{AER})}{(M_W + M_E)}$

Enter from line (10) Enter from line (12)

(18) $MCRT = \frac{(52{,}125 + 156{,}375)}{(31{,}275 + 4{,}337)} = 5.9$ days

Enter from line (14) Enter from line (16)

Determine Aerobic MCRT

(19) $$MCRT_{AER} = \frac{(M_{AER})(MCRT)}{(M_{AER} + M_{ANOX})}$$

Enter from line (12) Enter from line (18)

(20) $$MCRT_{AER} = \frac{(156{,}375)(5.9)}{(156{,}375 + 52{,}125)} = 4.4 \text{ days}$$

Enter from line (12) Enter from line (10)

Determine Anoxic MCRT

(21) $$MCRT_{ANOX} = (MCRT) - (MCRT_{AER})$$

(22) $$MCRT_{ANOX} = (5.9) - (4.4) = 1.5 \text{ days}$$

Enter from line (18) Enter from line (20)

Nitrogen Balance in a Nitrifying and Denitrifying Plant

Condition: 8 day MCRT, nitrification and denitrification

Required Input Data

(1)	Secondary effluent flow (assume equal to primary effluent flow)			**40**	mgd
(2)	Primary effluent TKN	**25**	mg/L	**8,340**	lbs/day
(3)	Primary effluent NOxN	**0**	mg/L	**0**	lbs/day
(4)	Nitrogen in waste activated sludge	**6.7**	mg/L	**2,242**	lbs/day
(5)	Secondary effluent NH_4^+-N	**1.0**	mg/L	**334**	lbs/day
(6)	Secondary effluent soluble org-N	**1.0**	mg/L	**334**	lbs/day
(7)	Nitrogen in secondary effluent SS	**1.2**	mg/L	**400**	lbs/day
(8)	Secondary effluent NOx-N	**6**	mg/L	**2,002**	lbs/day

Mass Balance Calculations (do in lbs/day first because it is easier)

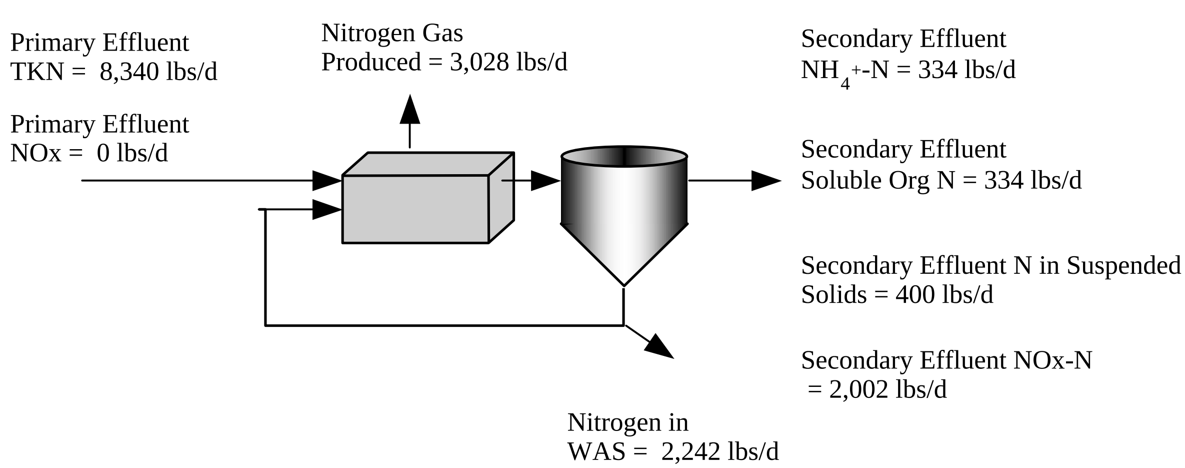
(9) Nitrogen Entering activated sludge system = Nitrogen leaving activated sludge system

(10) Nitrogen entering activated sludge system = Primary Effluent (TKN + NOxN)

(11) Nitrogen leaving activated sludge system = N in secondary effluent + N in WAS + N denitrified

Combining equations (10) and (11):

(12) Primary Eff (TKN+NOxN) = Sec Eff (NH_4N + Sol org N + N in SS + NOxN) + N in WAS + N denitrified



For operation with nitrification (medium to high MCRT with adequate aeration)

Nitrification is the difference between the <u>unoxidized-N</u> forms entering and leaving the activated sludge system

(12) Nitrification = Primary Effluent TKN - Secondary Effluent(NH_4^+-N + sol org N + N in TSS) - WAS org N

(13) Nitrification = (8,340) - (334 + 334 + 400) - (2,242) = 5,030 lbs/day or 15.1 mg/L

From line 2 From line 5 From line 7

From line 6 From line 4

Denitrification is the difference in <u>unoxidized and oxidized N</u> forms entering and leaving the activated sludge process.

(14) Denitrification = Primary Effluent (TKN + NOxN)

- Secondary Effluent (NH_4^+-N + sol org N + N in TSS + NOxN) - N in WAS

(15) Denitrification = (8,340 + 0) - (334 + 334 + 400 + 2,002) - (2,242) = 3,028 lbs/day

or 9.1 mg/L

From line 2 From line 5 From line 7 From line 4

From line 3 From line 6 From line 8

	Effluent NH_4^+-N	1	mg/L
(16)	Effluent SKN	2	mg/L
	Effluent TKN	3.2	mg/L
	Effluent NOxN	6.0	mg/L
	Effluent TN	9.2	mg/L

Solution:Exercise 5

BNR Troubleshooting

Attached is a plant data sheet for a BNR plant using a modified A^2/O process similar to the schematic shown in Transparency 98. The plant has effluent limits of 5 mg/L TN and 2 mg/L ammonia. The plant has automatic DO control in the first aerobic zone. It also has automatic methanol feed to the second anoxic zone based on feedback from a nitrate probe in the second aerobic zone. This data set indicates that the plant is achieving excellent nitrogen removal. The monthly average effluent total nitrogen of 4.4 mg/L meets the discharge permit limit of 5.0 mg/L. The monthly average effluent ammonia of 0.8 mg/L meets the discharge permit limit of 2.0 mg/L. There are, however, some days when minor problems occurred. Process adjustments during these times could have improved performance.

Can you identify three problems indicated by the data and recommend actions to improve performance?

1. On days 3 and 4 the MLSS concentration in the first anoxic zone dropped dramatically. Also denitrification in the first anoxic zone decreased, indicated by nitrate values of 6.8 and 7.1 in the first aerobic zone. The cause was a shutdown of the mixers in the anoxic zone resulting in settling of solids and decreased denitrification. The event adversely affected total nitrogen removal, with effluent TN values of 7.4 and 7.6. The system should have automatically increased methanol feed to remove more nitrate in the second anoxic zone. The feed system should be checked to be sure it is functioning properly.

2. Days 18, 19 and 20 were rainy resulting in a significant increase in plant flow. During this time, dissolved oxygen levels in the first aerobic zone increased to as high as 5.2 mg/L. Excess DO entering the second anoxic zone appears to have adversly affected denitrification in the second anoxic zone. DO levels may have increased due to higher water surface elevation in the oxidation ditch causing increased rotor aerator submergence. More dilute wastewater caused by inflow and infiltration from the storm event may have also contributed to the elevated DO level.

3. On days 14, 15 and 16 the DO in the first aerobic zone was at its lowest level of the month. This resulted in the highest effluent ammonias of the month (though still acceptable values). An increase in DO in the oxidation ditch may have improved nitrification and resulted in lower effluent ammonia on those days.