Technical Tale - Aerobic MCRT for Nitrification Control

Problem

A large activated sludge plant had to remove nitrogen down to an effluent ammonia concentration of about 3 mg/l (as N). Treatment to this degree essentially required that "complete nitrification" be achieved. Aerobic Mean Cell Residues Times (MCRT's) were found to be too low to ensure consistent/low effluent ammonia concentrations. This technical assistance story illustrates how important Aerobic MCRT is and how it turns nitrification on or off.

Aerobic MCRT Control

Nitrification is defined as the biological oxidation of ammonia to nitrate. Establishing a sufficient Aerobic MCRT is necessary to ensure an adequate nitrifier population.

Aerobic MCRT (days) is calculated as follows:

$$\text{(Total MCRT)} \times \frac{\text{Aerobic Volume}}{\text{Total Aeration Tank Volume}}$$

The Total MCRT (days) is the total pounds of biomass in system (aeration + clarifer) divided by the pounds of biomass lost and wasted per day.

The Minimum Aerobic MCRT required for nitrification is a function of nitrifier growth rate and death rate. The kinetic relationship is as follows:

$$\text{Minimum Aerobic MCRT} = \frac{1}{U_{max} - K_d}$$

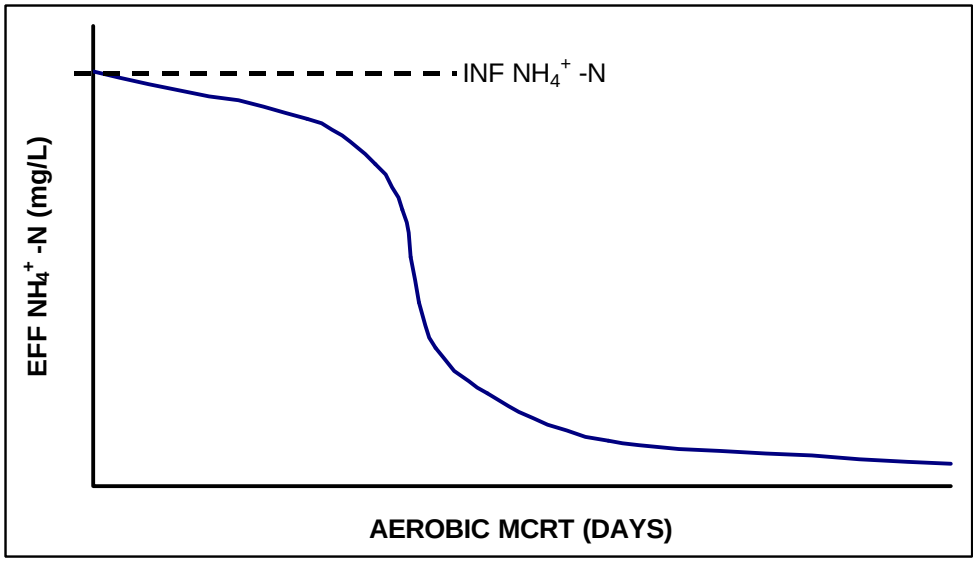
U_{max} = maximum nitrifier growth rate (1/days)

K_d = endogenous decay coefficient (1/days)

The U_{max} is affected by temperature, ammonia concentrations, dissolved oxygen, and pH.

Partial vs. Complete Nitrification?

Complete nitrification (effluent ammonia <2 mg/l) will only be achieved when the Minimum Aerobic MCRT is exceeded. The curve below shows the dramatic affect of Aerobic MCRT on nitrification. It is not possible/practical to control the process to partially nitrify to some pre-selected level e.g. Effluent Ammonia = 7.5 mg/l.



The MCRT data (see below) for the large activated sludge plant clearly shows the impact of too low Aerobic MCRTs - incomplete/partial nitrification.

Month	Required Minimum Aerobic MCRT (days)	Actual Aerobic MCRT (days)	Effluent NH_4 (mg/l)
May '97	4.4	2.8	7.0
June	4.0	3.1	6.4
July	3.4	2.3	16.3
Aug.	3.5	4.0	11.0
Sept.	3.6	4.3	3.0
Oct.	4.0	3.4	4.2
Nov.	4.8	4.4	4.6

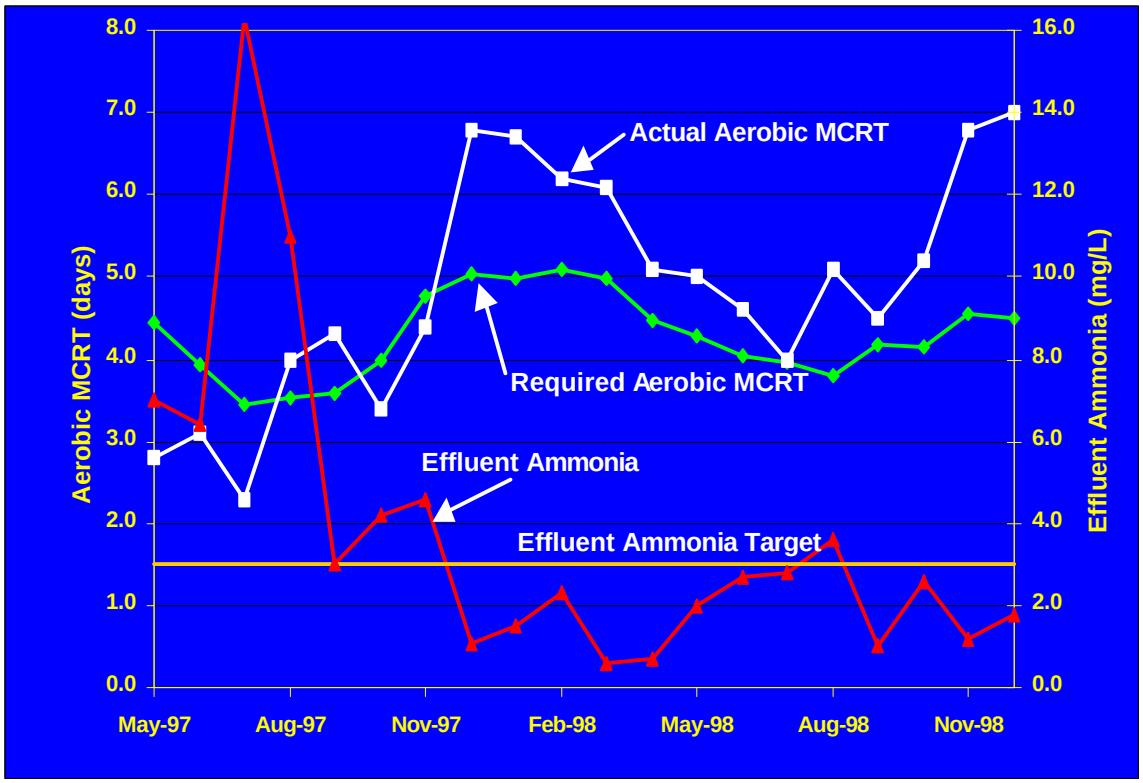
Process Control Change!

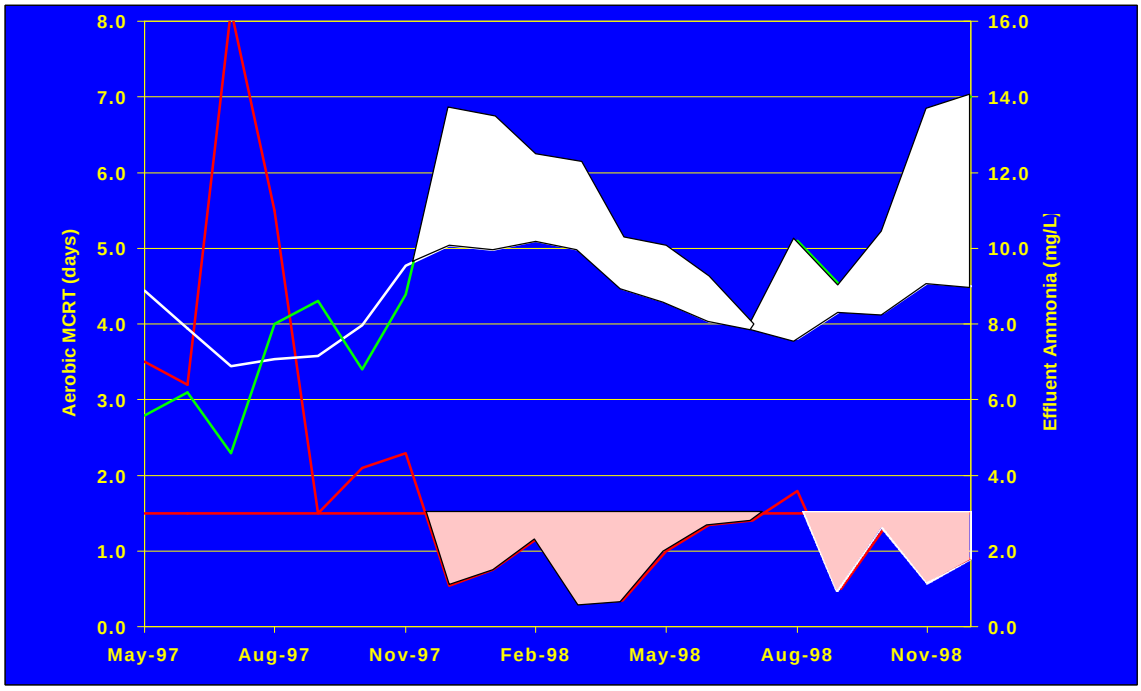
Mass/MLSS levels needed to be raised and higher Aerobic MCRT's were necessary to get complete nitrification. See Table 1 for all the data and also the two graphs. Note the importance of maintaining the "Actual Aerobic MCRT" greater than the minimum "Required Aerobic MCRT"...Complete nitrification from December 1977 on. Except in July 1978, when the "Actual Aerobic MCRT" got too close to the "Required Aerobic MCRT and resulted in an increase in effluent ammonia.

Assume Kd = 0.05
Assume Umax = 0.65
Desired Eff. NH4 = 3.0

MCRT APPROACH for NITRIFICATION

Month/Yr.	Aerator Temp(oC)	Temp CF 1.055(T-25)	uMax@T (days-1)	NH4 CF	Aeration DO's (mg/l)	DO CF	Corrected uMax (days-1)	Decay kD (days-1)	Required Aerobic MCRT (days)	Actual Aerobic MCRT (days)	Eff. NH4 (mg/l)	Actual MCRT (days)
May-97	18	0.687	0.447	0.814	2.5	0.714	0.260	0.03	4.4	2.8	7.0	4.1
Jun-97	20	0.765	0.497	0.797	2.8	0.737	0.292	0.04	3.9	3.1	6.4	4.5
Jul-97	22	0.852	0.554	0.779	3.4	0.773	0.333	0.04	3.4	2.3	16.3	3.0
Aug-97	22	0.852	0.554	0.779	3.1	0.756	0.326	0.04	3.5	4.0	11.0	7.0
Sep-97	21	0.807	0.525	0.788	3.4	0.773	0.319	0.04	3.6	4.3	3.0	5.6
Oct-97	20	0.765	0.497	0.797	2.7	0.730	0.289	0.04	4.0	3.4	4.2	4.0
Nov-97	16	0.618	0.401	0.829	2.6	0.722	0.240	0.03	4.8	4.4	4.6	5.4
Dec-97	15	0.585	0.381	0.837	2.5	0.714	0.227	0.03	5.0	6.8	1.1	9.5
Jan-98	15.6	0.605	0.393	0.832	2.4	0.706	0.231	0.03	5.0	6.7	1.5	9.8
Feb-98	15.4	0.598	0.389	0.834	2.3	0.697	0.226	0.03	5.1	6.2	2.3	9.7
Mar-98	15.6	0.605	0.393	0.832	2.4	0.706	0.231	0.03	5.0	6.1	0.6	8.7
Apr-98	17	0.652	0.424	0.822	2.8	0.737	0.256	0.03	4.5	5.1	0.7	6.9
May-98	18.8	0.718	0.466	0.807	2.5	0.714	0.269	0.04	4.3	5.0	2.0	6.4
Jun-98	21	0.807	0.525	0.788	2.3	0.697	0.288	0.04	4.0	4.6	2.7	5.9
Jul-98	21.9	0.847	0.551	0.780	2.2	0.688	0.295	0.04	4.0	4.0	2.8	4.8
Aug-98	23.3	0.913	0.593	0.767	2.1	0.677	0.308	0.05	3.8	5.1	3.6	5.8
Sep-98	22.5	0.875	0.569	0.774	1.8	0.643	0.283	0.04	4.2	4.5	1.0	5.6
Oct-98	20.7	0.794	0.516	0.791	2.2	0.688	0.281	0.04	4.2	5.2	2.6	6.4
Nov-98	18.5	0.706	0.459	0.809	2.2	0.688	0.255	0.04	4.5	6.8	1.2	8.3
Dec-98	17.4	0.666	0.433	0.818	2.6	0.722	0.256	0.03	4.5	7.0	1.8	8.8





Key Points

- Aerobic MCRT is a key control parameter for optimizing nitrification.
- Seasonal Target Aerobic MCRT's are necessary–Winter or Summer.
- Carry a higher Aerobic MCRT than theoretically required to accommodate for peak ammonia loadings.
- Avoid Aerobic MCRT's well beyond an optimum target level.
- Review and use lots of process control data to establish target MCRT's.
- Lower the Aerobic MCRT below the minimum to avoid nitrification.

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Go to "Nitrogen Removal Training Materials" Link for a more complete discussion of nitrifier growth rates and Aerobic MCRT control. "Control of Activated Sludge by Mean Cell Residence Time" by David Jenkins and Walter Garrison presented the original rational and was published in JWPCF in November 1968, p. 1905-1919.