Beyond Nitrification – Benefits of Higher SRT Operation

Michael K. Stenstrom
Civil and Environmental Engineering Department, UCLA
CWEA/AAEE Breakfast
April 15, 2011
Outline

• Introduction and Objective
  – Why operate at longer SRT?
  – What are the reasons other than nitrification?

• Enhanced removal of emerging contaminants

• Improved stability and biomass quality

• Energy conservation
Disadvantages

• Conventional Wisdom
  – Nitrification costs more, lots more, and is more difficult to operate and maintain
• Greater energy consumption due to greater oxygen uptake
• Greater aeration tank volumes
• Clarifier denitrification, nitrites interfering with disinfection
Advantages

• Improved emerging contaminants removal and soluble effluent quality

• Improved microbial environment
  – Selectors with denitrification
  – Particle size distribution

• Energy consumption
  – Improved efficiency with higher SRT
  – Denitrification credit
  – Reduced diffuser fouling

• Reduced biosolids production
Removal of Emerging Contaminants

About 80% of the pharmaceuticals, endocrine disrupters, hormones are degraded at high SRT, while most are not degraded at low SRT

Some literature examples (a few from my lab!)
Emerging Contaminants 1

(a) Sunscreen

Removal (%)

Oxybenzone
Benzophenone
Octylmethoxycinnamate
Emerging Contaminants 2

(b) Household

Removal (%) vs. Time

- Galaxolide
- Tonalide
- Methyl-3-phenylpropionate
- Triclosan
- Ethyl-3-phenylpropionate
- DEET
Emerging Contaminants 3

(c) Hormones

Removal (%) vs. Time

- Bisphenol-A
- 17α-Ethinylestradiol
- Total Estrogens (E1+E2+EE2)
Emerging Contaminants 4

(d) Pharmaceuticals

Percent Removal (%)

Solids Retention Time (day)

- Clara et al 2005
- Batt et al 2007
- Kreuzinger et al 2004
- Oppenheimer et al 2007
- Gobel et al 2007
- Joss et al 2004

- Diclofenac
- Sulfamethoxazole
- Ibuprofen
- Roxithromycin
- Carbamazepine
Traditional Modeling Result of Effluent Quality
Errors associate with typical measures like BOD & COD do not show improved efficiency
Improved BDOC Removal

![Graph showing BDOC removal with different SRT (days) and BDOC (mg/L) values for various locations and treatment methods.]

- Conventional AS (CAS)
- HPO AS
- CAS with nutrient removal (NR)
- Trickling filter followed by CAS with NR
Improved Biomass Quality

• Anoxic selector effect

• Reduced incidences of filamentous bulking

• Clearer, less turbid effluents
Particle Size Distribution

Sacramento Regional 2009
MLSS 120509-1
MLSS 120509-2
MLSS 120509-3
MLSS 120509-4
Calculating Mean Particle Size

Total Particles  =  \int_{0.5}^{M} Nds

First Moment  =  \int_{0.5}^{M} S \cdot Nds

PAS  =  \frac{\int_{0.5}^{M} S Nds}{\int_{0.5}^{M} Nds}
Impacts to Effluent Quality?

MLSS PAS and total particle numbers of supernatant for particles integrated to 200 um
Supernatant Particles vs SRT

Graph showing the number of particles in supernatant versus SRT. The x-axis represents SRT ranging from 0 to 35, and the y-axis represents the number of particles in the supernatant ranging from $10^4$ to $10^7$. The data points are scattered on a logarithmic scale, indicating a decrease in particle count as SRT increases.
# Three Plants Monitored Using Off-Gas Analysis

<table>
<thead>
<tr>
<th>Test Plant</th>
<th>Phase</th>
<th>Process</th>
<th>SRT (day)</th>
<th>Flow Rate per Tank (10^3 m^3/day)</th>
<th>Flow Rate per Tank (MGD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant I</td>
<td>1</td>
<td>Conventional</td>
<td>1.6 - 1.9</td>
<td>18.8</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Conventional</td>
<td>2.6 - 3.5</td>
<td>15.1</td>
<td>4.0</td>
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<tr>
<td></td>
<td>3</td>
<td>NDN (Partial)</td>
<td>6.4 - 7.0</td>
<td>17.0</td>
<td>4.5</td>
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<tr>
<td></td>
<td>4</td>
<td>NDN (Full)</td>
<td>11.0 - 12.2</td>
<td>16.3</td>
<td>4.3</td>
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<tr>
<td>Plant II</td>
<td>1</td>
<td>Conventional</td>
<td>3.1 - 4.1</td>
<td>15.5</td>
<td>4.1</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>NDN (Full)</td>
<td>12.5 - 14.0</td>
<td>11.4</td>
<td>3.0</td>
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<tr>
<td>Plant III</td>
<td>1</td>
<td>Conventional</td>
<td>3.3 - 4.5</td>
<td>79.8</td>
<td>21.1</td>
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<tr>
<td></td>
<td>2</td>
<td>Nitrification only</td>
<td>14.0 - 17.3</td>
<td>37.2</td>
<td>9.9</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Conventional</td>
<td>1.8 - 2.5</td>
<td>37.2</td>
<td>9.9</td>
</tr>
</tbody>
</table>
Relative Aeration Efficiency

Fraction of $\alpha$SOTE per $\alpha$SOTE$_{SRT<2}$

Solids Retention Time (day)

$SOTE_{SRT<2}$ (Plant I) = 10.9%
Rate of Diffuser Fouling

- Conventional Process
- NdN Process
Relative Cost of Aeration vs SRT

Change of aeration energy \( \left( \frac{E_A}{E_{AI}} \right) \)

- Conv. - Nitrify only
- Conv. - NdN
- Measurements

Aeration power per volume wastewater treated (MJ/10^3 m^3)

Solids Retention Time (day)
Process Modifications

• Analysis was performed for “warm” climates. Conversion to longer SRT and NDN occurred with little or no plant capacity derating

• Improved OTE confirmed in colder climates

• Increases in aeration time at colder temperatures not investigated and increased tankage should be anticipated
Conclusions

• Higher SRT produces superior quality effluent with respect to numbers and sizes of particles
• Higher SRT produces effluent lower in biodegradable organic carbon
• Literature review and some of our data show that many (~80%) of the emerging contaminants have superior removal at higher SRT. (Degradation or adsorption mechanisms)
• Improved aeration efficiency off-sets much of the energy associated with the increased OUR
• Reduced rates of diffuser fouling will improve the energy trade off to higher SRT