Lagoon Solutions: Treatment Performance and Nutrient Removal

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Agenda

- Compliance and Capacity
- Lagoon Aeration
- Lagoon Processes
  - Traditional
  - Review of Advanced Technologies
- Final Thoughts
- Q&A
Compliance and Capacity
Compliance and Capacity

• VAST
  – Volume
  – Aeration
  – Short-circuiting
  – Temperature
Lagoon Aeration
Lagoon Aeration – Why Aeration?

- Aerobic (Oxygen)
- Anoxic (Nitrate/Nitrite)
- Anaerobic (Iron, Manganese, Sulfate...)
Lagoon Aeration – Why Aeration?

Aerobic (Oxygen)

Anoxic (Nitrate/Nitrite)
Lagoon Aeration – What to Use?

• Surface vs. Diffused Aeration
  – Surface
    • Easy, less expensive to install
  – Diffused
    • Higher energy efficiency
      – Generally 40-50% the power for equivalent oxygen
Lagoon Aeration – What to Use?

• Fine Bubble vs. Coarse Bubble
  – Fine Bubble
    • SOTE 1.5-2.2%/ft
    • Maintenance requirement (membrane changes)
      – Backflow prevention
    • Head loss across membrane
      – May increase or decrease with age and use
    • Greater volumetric pumpage for mixing (than coarse bubble)
Lagoon Aeration – What to Use?

- Fine Bubble vs. Coarse Bubble
  - Coarse Bubble
    - SOTE 1%/ft
    - No maintenance expected
    - Nominal head loss
    - Less volumetric pumpage for mixing (than fine bubble) but able to lift heavy particles with focused suction (i.e., airlift pump)
Lagoon Aeration – What to Use?

• Fine Bubble and Coarse Bubble
  – Challenges of combining the two:
    • Engineered orifice satisfies design at one airflow rate
      – High or lower air flow results in disproportionate air flow to coarse
    • Less efficient overall
      – Combining 2%/ft with 1%/ft must result in higher air flow than 2%/ft throughout
    • No mixing advantage for the addition of sparsely-placed airlift pumps
Lagoon Processes
Lagoon Processes - Traditional

• Four Primary Types:
  – Anaerobic
    • Covered (welded), no oxygen, mostly industrial
  – Facultative
    • Atmospheric oxygen, also as QZ for settling
  – Partial Mix
    • Aeration, minimal suspension of solids
  – Complete Mix
    • Aeration, homogenous conditions
Lagoon Processes - Traditional

- Partial Mix Design

  - For BOD: \( \frac{C_e}{C_0} = \frac{1}{1 + \left( \frac{kt}{n} \right)^n} \)
  
  - \( t = \text{hrt (days)} \)
  - \( n = \# \text{ of ponds} \)
  - \( k = 0.276 \text{ /day @ 20° C} \)
  
  - \( Kt = 0.276 \times 1.036^{T-20} \)
Lagoon Processes - Traditional

• Complete Mix Design

  – For BOD: \( \frac{C_e}{C_0} = \frac{1}{1 + \left(\frac{kt}{n}\right)^n} \)

  • \( t = \text{hrt (days)} \)
  • \( n = \# \text{ of ponds} \)
  • \( k = 2.5 \ @ \ 20^\circ \text{C} \  (\text{Note: PM = 0.276}) \)
    – \( Kt = 2.5 \ * \ 1.036^{T-20} \)
Lagoon Processes - Traditional

• Complete vs. Partial Mix Design
  – What does “completely mixed” mean?
  • Is this really a step function?

![Diagram showing BOD Removal Rate (k) vs. Air Flow or Mixing Energy with labels for Complete Mix and Partial Mix. The Partial Mix has a 7 scfm/1,000 ft³ requirement.]
Lagoon Processes - Traditional

• Complete vs. Partial Mix Design
  – What does “completely mixed” mean?
    • Is it linear?
    • Or sinusoidal?

BOD Removal Rate vs. Air Flow or Mixing Energy

- Complete Mix
- Partial Mix

8 scfm/1,000 ft³
Lagoon Processes - Traditional

• Complete vs. Partial Mix Design
  – What does “completely mixed” mean?
    • Is it linear?
    • Or sinusoidal?

There is no accepted lagoon model known as “Vigorously Mixed”
Lagoon Processes - Traditional

• Complete vs. Partial Mix Design
  – What does “completely mixed” mean?
    • Energy input is only one dimension
    • What about distribution of energy?
Review of Advanced Technologies
Review of Advanced Technologies

• Front-of-the-Plant
  – Advantages
    • Decreased footprint
    • Total nitrogen removal
    • Reduced energy
      – Shared blowers for BOD/ammonia
      – Denitrification reduces energy cost (use nitrate vs. oxygen)
Review of Advanced Technologies

• Front-of-the-Plant
  – Disadvantages
    • Sludge management
      – Wasting rates/timing
      – Sludge removal from digester
    • Increased mechanical components
      – Valves, pumps, clarification equipment, etc.
    • Potentially more complicated construction project
      – Maintaining lagoon operation, dirt work, etc.
Review of Advanced Technologies

• Front-of-the-Plant Treatment Examples
  – Lagoon-Based Batch Reactors
    • w/ or w/o attached growth
Review of Advanced Technologies

• Front-of-the-Plant Treatment Examples
  – Lagoon-Based Batch Reactors
    • w/ or w/o attached growth
  – Activated Sludge Lagoons
Review of Advanced Technologies

• Back-of-the-Plant
  – Advantages
    • Potentially less invasive construction
      – “Drop in” options may require little site modification
    • Easy to operate/maintain
    • Demonstrated extreme cold performance
Review of Advanced Technologies

• Back-of-the-Plant
  – Disadvantages
    • Must address variable loading and temperature
      – The one/two punch of fall/winter nitrification
Review of Advanced Technologies

• Back-of-the-Plant
  – Addressing variable loading and temperature

### Summer

- **Existing Lagoon System**
  - 25° C
  - 30 mg/L

- **Post-Lagoon Ammonia Treatment**
  - 25° C
  - 0.5 mg/L
  - 5 mg/L
Review of Advanced Technologies

- Back-of-the-Plant
  - Addressing variable loading and temperature

![Diagram showing water treatment process]

- Existing Lagoon System
  - Input: 30 mg/L
  - Temperature: 10°C

- Post-Lagoon Ammonia Treatment
  - Output: 5 mg/L
  - Temperature: 10°C

Fall
Review of Advanced Technologies

- **Back-of-the-Plant**
  - Addressing variable loading and temperature

**Winter**

- **Existing Lagoon System**: 30 mg/L → 1°C
- **Post-Lagoon Ammonia Treatment**: 28 mg/L → 1°C

- **Winter**: 20 mg/L
Review of Advanced Technologies

• Back-of-the-Plant
  – Disadvantages
    • Must address variable loading and temperature
      – Solutions:
        » Thermal Covers (normalize temperature)
        » Re-Heat Water (Since at least 2006)
        » Bioaugmentation
        » Step-Feed/Short-Circuit
Review of Advanced Technologies

• Back-of-the-Plant
  – Disadvantages
    • Must address variable loading and temperature
    • Filtration may be necessary
    • Full sludge removal may be necessary
    • Total nitrogen removal difficult/complicated
    • Potential long term viability issues
Review of Advanced Technologies

- Back-of-the-Plant Treatment (Examples)
  - IFAS (MBBR) w/ clarifier or filter
Review of Advanced Technologies

- Back-of-the-Plant Treatment (Examples)
Review of Advanced Technologies

• Back-of-the-Plant Treatment (Examples)
Final Thoughts
Final Thoughts

• Increasing Capacity (VAST)
  – Volume (sludge)
  – Aeration
  – Short-circuiting
  – Temperature

• No Silver Bullet
  – Front/Back-of-the-Plant dependent on client, operator, site limitations, and personal preference
  – All have advantages and disadvantages

• Design only as good as inputs
  – Influent studies needed!!!
Q&A

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