AEROBIC DIGESTION
Not the Same Old Same Old

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Aerobic Digestion

Not Treatment of Raw Waste

Endogenous Respiration

\[ \text{All Bugs + No Food = Cannibalism} \]

Reduces Volatile Solids

Kills Pathogenic Organisms
### Aerobic Digestion

#### Pros and Cons

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower capital costs for facilities with capacities less than 19,000 m³/day (5 MGD)</td>
<td>Higher operating costs and other operational issues when treating primary sludge</td>
</tr>
<tr>
<td>Minimal nuisance odors (except for short SRT ATAD processes)</td>
<td>Higher energy costs than other stabilization processes, especially traditional mesophilic anaerobic digestion</td>
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<tr>
<td>Simple construction</td>
<td>Limited pathogen reduction (except for ATAD)</td>
</tr>
<tr>
<td>No danger of explosions or suffocations</td>
<td>Lower cake solids (except for some ATAD processes)</td>
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<tr>
<td>Simple operation</td>
<td>Potential for alkalinity depletion if nitrification occurs</td>
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<tr>
<td>Weaker sidestreams</td>
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<tr>
<td>Less impact from low pH</td>
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</table>
What is the End Use?

Marketing/Distribution?
- Class A Pathogen Reduction
- EQ Class Requirements

Public Access?
- Class A Pathogen Reduction

Landfill?

Restricted Access?
- Class B Pathogen Reduction

Vector Attraction Reduction Criteria
Aerobic Digestion and Pathogen Reduction

- Class A Pathogen Reduction
  - PFRP Processes
    - Thermophilic Aerobic Digestion
  - PFRP-Equivalent Processes
    - ATAD – Autothermal Thermophilic Aerobic Digestion
    - Alternative 1 – Time/Temperature (Thermophilic Systems)

- Class B Pathogen Reduction
  - PSRP - Specifically Defined Operating Criteria (40 CFR 257)
    - Aerobic Digestion
  - Alternative 1 - Testing
What’s Not Listed?

Unless Defined Criteria Are Met, Digestion Processes Are Not PFRP or PSRP

For PFRP
- May Meet Alternative 1, if Process is Thermophilic
- May Meet Alternative 4 (Testing)
- Less Desirable

Alternative Processes – NOT LISTED
- Thickened Aerobic Digestion Modifications
- Aerobic/Anoxic Digestion
- Aerobic/Anaerobic Digestion
- Most Proprietary Processes
Autothermal thermophilic aerobic digestion (ATAD) is listed as a PFRP process.

True

False
All solids treated with a PFRP can be reused through marketing and distribution.

True

False
Aerobic Digestion and Vector Attraction Reduction

Option 1 - Volatile Solids Reduction (38%)

- Measured From Entry to Solids Process
- Up to 50% - Dependent on Prior Processes
- More Difficult with Extended Aeration Processes
  - 20-25% Of Influent Solids Are Refractory
Calculating Volatile Solids Reduction

Not (Mass In – Mass Out)/Mass In

Appropriate Method Varies

Depends Upon

   Grit Accumulation

   Decantate Removal
### Appropriate Methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Full Mass Balance</th>
<th>Approx. Mass Balance</th>
<th>Van Kleeck</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Decantate/ No Grit Accumulation</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Grit Accumulation</td>
<td></td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Decantate Withdrawal</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Decantate Withdrawal and Grit Accumulation</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>
Van Kleeck Equation

\[ F_{VSR} = \frac{V_{S_f} - V_{S_b}}{V_{S_f} - (V_{S_f} \times V_{S_b})} \]

Where:

- \( F_{VSR} = \) Fractional Volatile Solids Reduction
- \( V_{S_f} = \) Feed Sludge Fractional Volatile Solids (kg/kg)
- \( V_{S_b} = \) Digested Sludge Fractional Volatile Solids (kg/kg)
Aerobic Digestion and Vector Attraction Reduction

Other Available Options:

Option 3 – Additional Digestion of Aerobically Digested Sewage Sludge
Limited to Sludges with 2% or less Solids
Thicker Sludges Can Be Diluted
Less than 15% Additional Reduction after Additional 30 Days

Option 4 – Specific Oxygen Uptake Rate (SOUR)
Limited to Sludges with 2% or less Solids
Dilution is not allowed
Sludges from 10 - 30°C (50 – 86°F)
During Summer, Sludge May Be Warmer
Not Suitable for Thermophilic Systems
Holding Time Less Than 2 hours
An aerobic digester is operated with good mixing and bottom withdrawal of biosolids (no grit accumulation). Telescoping valves are used to periodically decant the digester. Volatile Solids Reduction can be calculated using

a. The Van Kleeck Equation
b. Approximate Mass Balance
c. Full Mass Balance
d. All of the Above
e. Can not be solved
A treatment plant utilizes aerobic digestion, with typical summer temperatures (both air and liquid) over 85 degrees F. The sludge is thickened to 2.5% solids in the digester. Vector attraction reduction criteria can be demonstrated using:

(Select all that apply)

a. Option 1 – Volatile Solids Reduction
b. Option 3 – Additional Aerobic Digestion
c. Option 4 – SOUR test
Aerobic Digestion (Conventional)

Class B Process – Defined as PSRP
PSRP Operational Criteria
- 40 Days at 20 Degrees C
- 60 Days at 15 Degrees C
No Allowance for Temperatures Outside This Range
Detention Time Credit for Two-Stage (True Series) Operation
- Referenced in EPA Documents, Up to State Regulatory Agency
- 30% Reduction in Detention Time (Required Volume)
- Also valid for true Batch Operation (Draw, then Fill)
Aerobic Digestion Fundamentals

Based on Endogenous Respiration
- \( C_5H_7O_2N + 5O_2 \rightarrow 4CO_2 + H_2O + NH_4HCO_3 \)
- Produces both Ammonia and Alkalinity

If Sufficient Oxygen is Provided
- \( NH_4 + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O \)
- Consumes Alkalinity

If Alkalinity drops low enough, only partial nitrification
- \( 2C_5H_7O_2N + 12O_2 \rightarrow 10CO_2 + 5H_2O + NH_4^+ + NO_3^- \)
Calculating Detention Time

Two Factors:

- Regulatory Requirements - Class B Process
- Biological Requirements

See Handout
Aerobic digestion consumes alkalinity.

a. True
b. False
c. Depends upon the extent of aeration
At 20 degrees C, if an aerobic digester is operated in series, the minimum allowable detention time is:

a. 40 days
b. 42 days
c. 60 days
d. none of the above
Oxygen Requirements

Theoretical: 1.5/2.0 kg O\(_2\)/kg active cell mass
Field: 2.0 kg O\(_2\)/kg active cell mass

+ 1.6 to 1.9 kg O\(_2\)/kg VS destroyed for Primary Sludge
Oxygen Transfer/Mixing Requirements

At 1 to 2% Solids, mixing will typically govern

Mixing Requirements:

10 to 100 W/m³ (0.5 to 4.0 hp/1000 cu ft)

0.33 to 0.50 L/m³•s (20 to 30 cu ft/min/1000 cu ft)

Typical Oxygen transfer requirements (not thickened)

WAS ONLY - 0.25 to 0.33 L/m³•s (15 to 20 cu ft/min/1000 cu ft)

PRIMARY AND WAS - 0.40 to 0.50 L/m³•s (25 to 30 cu ft/min/1000 cu ft)

DO Typically Maintained at 2.0 mg/L, unless OUR < 20 mg/L•h
Aeration Methods

Mechanical Aerators
Coarse Bubble
Fine Bubble
Jet Aeration
Other
Mechanical Aerators

Photos courtesy Evoqua Water Technologies
Coarse Bubble Aeration

Photos courtesy Evoqua Water Technologies
Fine Bubble Aeration

Photos courtesy Evoqua Water Technologies
Jet Aeration
For digesters without primary sludge, 20 to 30 SCFM/1000 ft$^3$ will typically provide sufficient energy for mixing and sufficient oxygen for aeration.

True

False
The typical oxygen requirement for aerobic digesters (without primary sludge) is:

a. 2.0 kg O$_2$/kg VS
b. 10 SCFM/1000 ft$^3$
c. none of the above
Instrumentation & Controls

Not Mandatory, But Helpful

Typical Controls:

- Dissolved oxygen
- ORP – can be beneficial either for anoxic/aerobic systems or thermophilic systems
- Tank level control
## Sidestream Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Typical Range</th>
<th>Acceptable Value</th>
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</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.9-7.7</td>
<td>7.0</td>
</tr>
<tr>
<td>5-day BOD (mg/L)</td>
<td>9-1700</td>
<td>500</td>
</tr>
<tr>
<td>Filtered 5-day BOD (mg/L)</td>
<td>4-173</td>
<td>50</td>
</tr>
<tr>
<td>Suspended Solids (mg/L)</td>
<td>46-2000</td>
<td>1000</td>
</tr>
<tr>
<td>Kjehldahl Nitrogen (mg/L)</td>
<td>10-400</td>
<td>170</td>
</tr>
<tr>
<td>Nitrate-nitrogen (mg/L)</td>
<td>0-30</td>
<td>10</td>
</tr>
<tr>
<td>Total Phosphorus (mg/L)</td>
<td>19-241</td>
<td>100</td>
</tr>
<tr>
<td>Soluble Phosphorus (mg/L)</td>
<td>2.5-64</td>
<td>25</td>
</tr>
</tbody>
</table>
Controlling Nutrients

Nitrogen Control
  Aerobic/Anoxic Operation

Phosphorus Control
  Controlling Phosphorus to Disposal
  Controlling Phosphorus in Sidestream
Aerobic/Anoxic Operation

Aeration cycling promotes denitrification
- Lower DO to less than 1 mg/L (maintain mixing)
- ORP Control beneficial
- Reduces energy demand (up to 18%)
- Alkalinity credit (up to 50%)

\[
C_5H_7O_2N + 4NO_3^- + H_2O \rightarrow NH_4^+ + 5HCO_3^- + 2N_2\uparrow
\]

Equations Combine
\[
2C_5H_7O_2N + 11.5O_2 \rightarrow 10CO_2 + N_2 + 7H_2O
\]
Nitrogen goes to atmosphere – not sludge or recycle…

From Al-Ghusain et al, 2004
Phosphorus Control

Not Destroyed

Either To Disposal or To Effluent

Release in Aerobic Digesters is Less

Limiting Sidestream P Concentrations

Aerobic/Anoxic Operation (~50% Reduction vs Continuous Aeration)

pH Control

pH <6 increases release

Lime addition reduces release

Partial Nitrification => Formation/Removal of Struvite
Keys to Design

Take Advantage of the Series “Credit” – 30% Reduction in Volume
- At least two tanks
- Draw, then fill

Provide Enough Air
- Fine bubble aeration is possible
  - Energy savings, but higher maintenance
- Ability to re-suspend solids, or provide mixers + aeration
  - Allows anoxic/aerobic cycling and denitrification
- Allow for primary sludge requirements
- Thickening decreases aeration efficiency (>~3% solids)

Utilize in-tank thickening where feasible
- Further reduces tank volume
Pick which of the following statements is true.

a. Anoxic/aerobic digestion will increase the supernatant phosphorus concentration.

b. Anoxic/aerobic digestion will decrease the supernatant nitrogen concentration.

c. Anoxic/aerobic digestion will increase supernatant phosphorus and nitrogen concentrations.
Turning the air off in an aerobic digester for up to 8 hours will have an adverse impact on the digester supernatant.

a. True
b. False
Design Techniques to Optimize Digestion

Do Not Result in PFRP or PFRP-equivalency
- May Meet Class A Using Other Alternatives
- May Reduce Capital Costs

Thickening
- Decreases volume required for given HRT
- Negatively impacts aeration efficiency
- Multiple Variants – Pre-thickening, In-loop, Post-thickening

Aerobic/Anoxic Operation
Digester Decanting

Can be Batch Operation or Decanting
Can Achieve Up to 2.5% Solids

Advantages
- No additional basins are required
- Possible to use existing tanks to both thicken and digest

Disadvantages
- Larger basins required (low solids concentration prior to decanting)
- Varying liquid levels may impact aeration efficiency
- No control of alkalinity, temperature, nitrogen or phosphorus
In-Loop (Recuperative) Thickening

Two Main Phases
- In-loop
- Isolation

Four Main Basins
- Two digesters, One premix, one thickener

Advantages
- Provides benefits of anoxic/aerobic operation
- Controls nitrogen and phosphorus in supernatant

Disadvantages
- Higher capital cost
Membrane Thickening

Membranes can be mounted in digester basin or in separate basin
Operated in batch or continuous mode

Advantages
- Physical barrier of membrane provide best control of supernatant quality
- Small footprint
- Control of solids concentration

Disadvantages
- Capital cost
Post-thickening

Resembles Activated Sludge Process – Separation/Thickening Downstream of Digestion

Advantages
- Digester operates at fixed level – overflow goes to separator

Disadvantages
- Digesters sized based on lower solids concentration
- Higher O&M costs
- No control of alkalinity, temperature, nitrogen or phosphorus
Impact of Solids on Aeration

Alpha Factors vs MLSS

From MBR Research
Coarse Bubble $\alpha$ varies widely
  Data from membrane tank
Focus on trend, not #
Verify w/ manufacturer
Dramatic decrease
Due to viscosity

Source: Final Report, WERF Project #00-CTS-8a, MBR Website Strategic Research, Relationship between MLSS and Oxygen Transfer Efficiency in MBR Systems
Alpha factors:

1. Increase with solids concentration for both coarse and fine bubble diffusers

2. Decrease with solids concentration for both coarse and fine bubble diffusers

3. Increase with solids concentration for coarse bubble diffusers but decrease with concentration for fine bubble diffusers.
Which of the following methods is NOT a way to reduce aerobic digester volumes required to meet the SRT requirements for PSRP?

1. Decant the digester to remove supernatant
2. Provide in-loop membrane thickening
3. **Dewater digested solids using centrifuges**
4. Utilize two stages in series
Thank You!