AEROBIC DIGESTION

Not the Same Old Same Old

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Aerobic Digestion

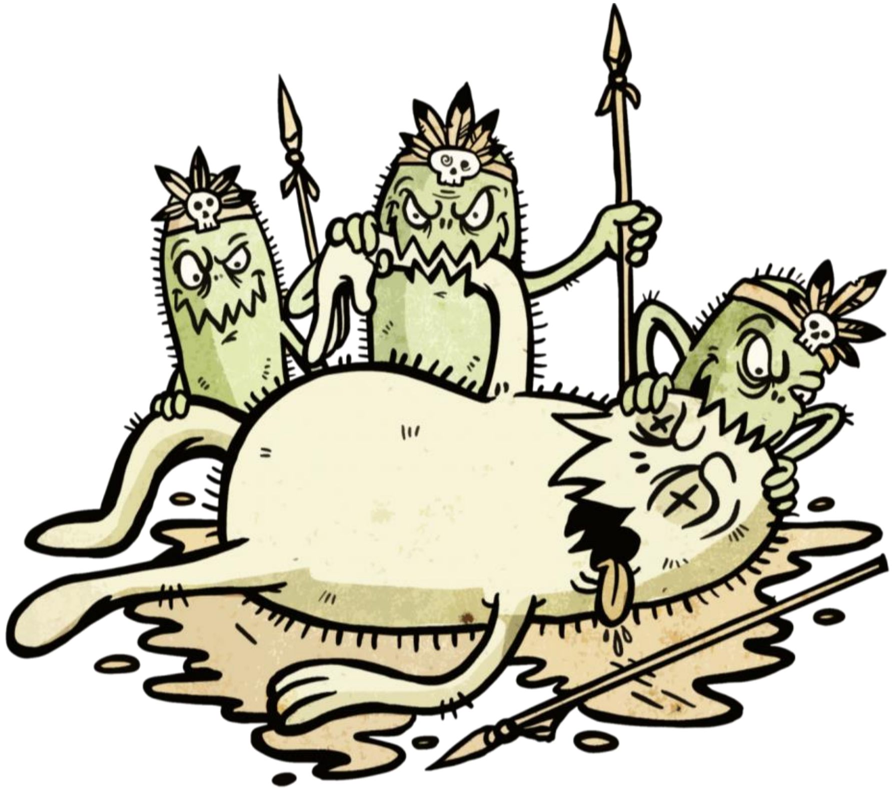
Not Treatment of Raw Waste

Endogenous Respiration

- All Bugs + No Food = Cannibalism

Reduces Volatile Solids

Kills Pathogenic Organisms



Aerobic Digestion Pros and Cons

Advantages	Disadvantages
Lower capital costs for facilities with capacities less than 19,000 m^3/day (5 MGD)	Higher operating costs and other operational issues when treating primary sludge
Minimal nuisance odors (except for short SRT ATAD processes)	Higher energy costs than other stabilization processes, especially traditional mesophilic anaerobic digestion
Simple construction	Limited pathogen reduction (except for ATAD)
No danger of explosions or suffocations	Lower cake solids (except for some ATAD processes)
Simple operation	Potential for alkalinity depletion if nitrification occurs
Weaker sidestreams	
Less impact from low pH	

What is the End Use?

Vector Attraction Reduction Criteria

Marketing/Distribution?

- Class A Pathogen Reduction
- EQ Class Requirements

Public Access?

- Class A Pathogen Reduction

Restricted Access?

- Class B Pathogen Reduction

Landfill?

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

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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

	Full Mass Balance	Approx. Mass Balance	Van Kleeck
No Decantate/ No Grit Accumulation	√	√	√
Grit Accumulation	√	√	
Decantate Withdrawal	√	√	√
Decantate Withdrawal and Grit Accumulation	√	√	

Van Kleeck Equation

$$FVSR = \frac{VS_f - VS_b}{VS_f - (VS_f \times VS_b)}$$

Where:

FVSR = Fractional Volatile Solids Reduction

VS_f = Feed Sludge Fractional Volatile Solids (kg/kg)

VS_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

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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

- $C_5H_7O_2N + 5O_2 => 4CO_2 + H_2O + NH_4HCO_3$
- Produces both Ammonia and Alkalinity

If Sufficient Oxygen is Provided

- $NH_4 + 2O_2 => NO_3^- + 2H^+ + H_2O$
- Consumes Alkalinity

If Alkalinity drops low enough, only partial nitrification

- $2C_5H_7O_2N + 12O_2 => 10CO_2 + 5H_2O + NH_4^+ + NO_3^-$

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/m^3 (0.5 to 4.0 hp/1000 cu ft)
- 0.33 to 0.50 L/m^3•s (20 to 30 cu ft/min/1000 cu ft)

Typical Oxygen transfer requirements (not thickened)

- WAS ONLY - 0.25 to 0.33 L/m^3•s (15 to 20 cu ft/min/1000 cu ft)
- PRIMARY AND WAS - 0.40 to 0.50 L/m^3•s (25 to 30 cu ft/min/1000 cu ft)

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

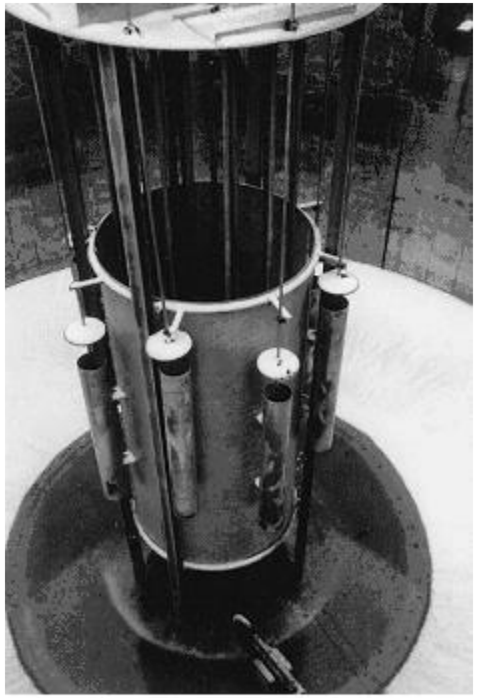
Aeration Methods

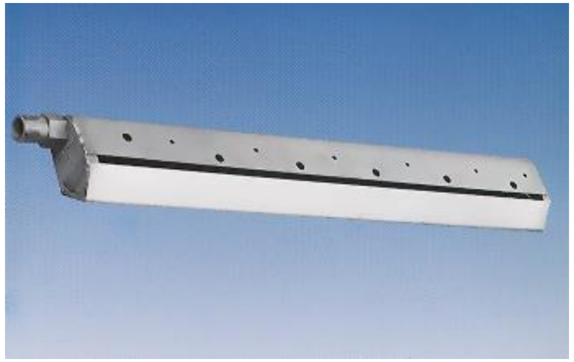
- Mechanical Aerators
- Coarse Bubble
- Fine Bubble
- Jet Aeration
- Other

Mechanical Aerators

Photos courtesy Evoqua Water Technologies

Coarse Bubble Aeration





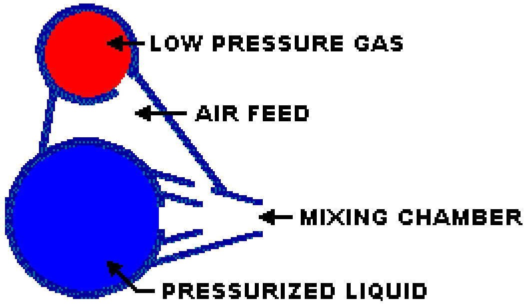
Photos courtesy Evoqua Water Technologies

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

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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

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

Controlling Nutrients

Nitrogen Control

- Aerobic/Anoxic Operation

Phosphorus Control

- Controlling Phosphorus to Disposal
- Controlling Phosphorus in Sidestream

Aerobic/Anoxic Operation

Aeration cycling promotes denitrification

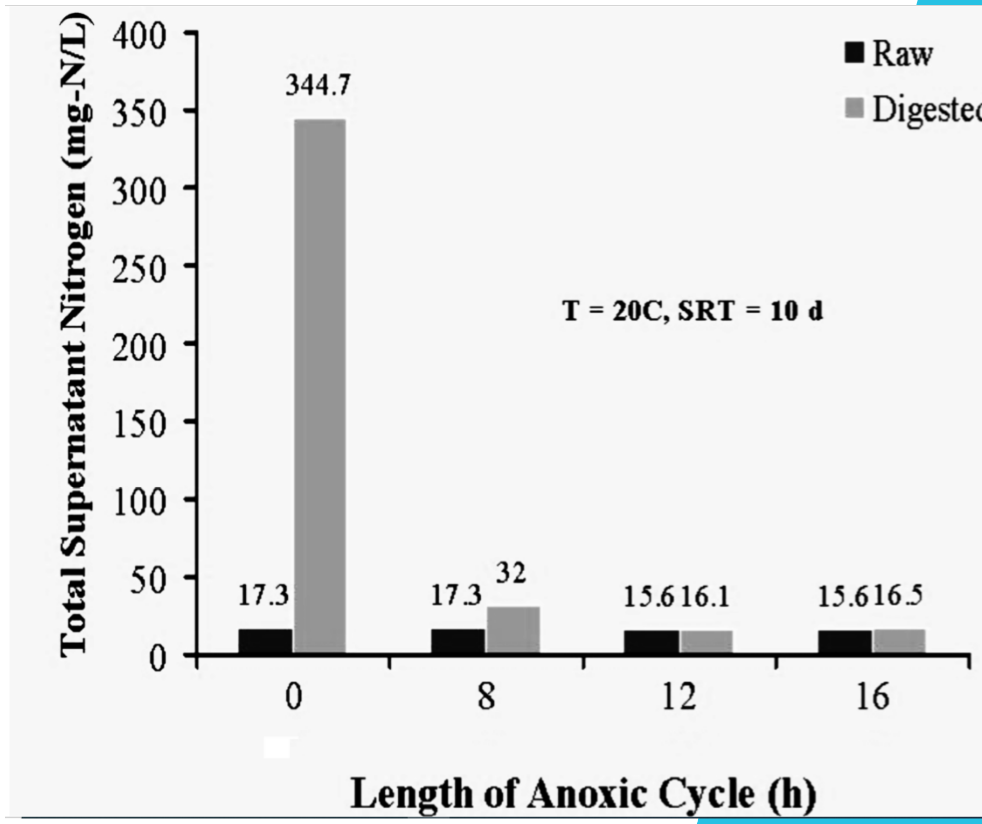
- Lower DO to less than 1 mg/L (maintain mixing)
- ORP Control beneficial
- Reduces energy demand (up to 18%)
- Alkalinity credit (up to 50%)

$C_5H_7O_2N + 4NO_3^- + H_2O \Rightarrow NH_4^+ + 5HCO_3^- + 2N_2\uparrow$

Equations Combine

$2C_5H_7O_2N + 11.5O_2 \Rightarrow 10CO_2 + N_2 + 7H_2O$

Nitrogen goes to atmosphere – not sludge or recycle…



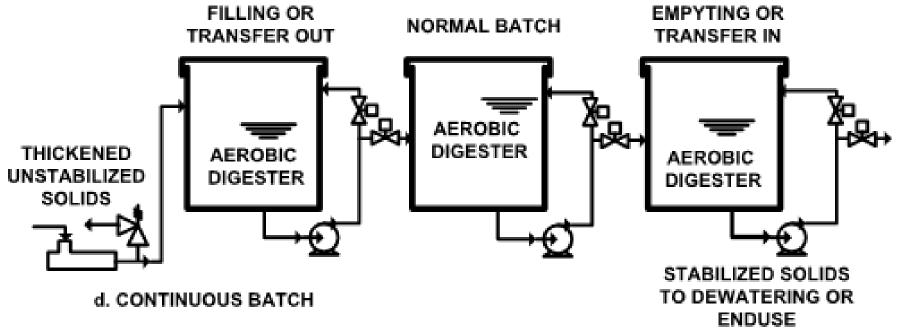
From Al-Ghusain et al, 2004

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



d. CONTINUOUS BATCH

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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.

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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

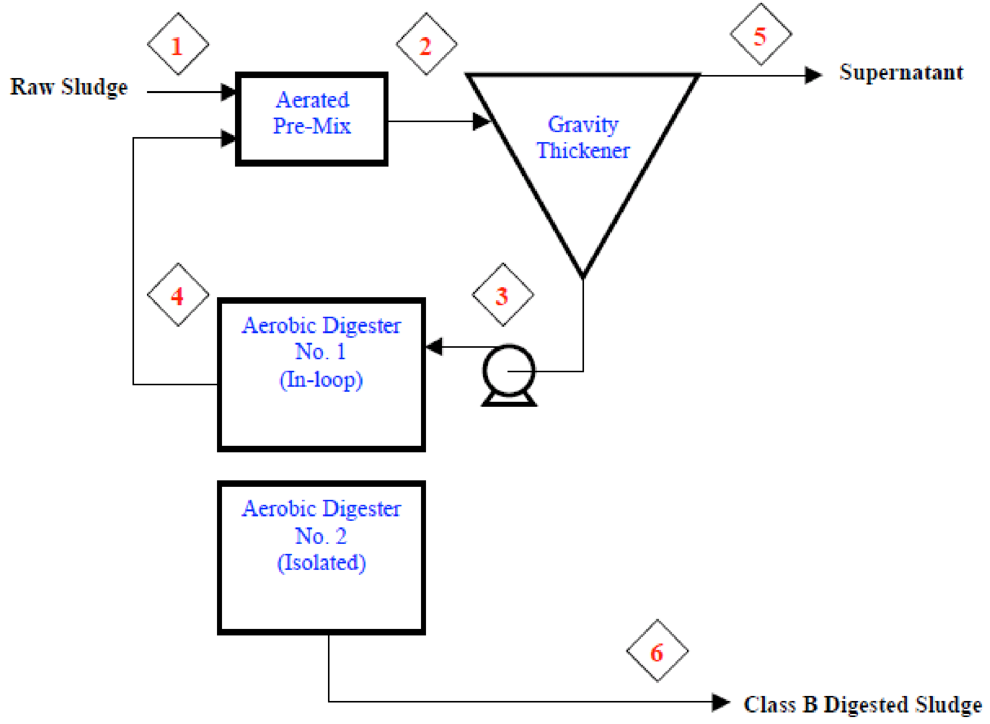
- No additional basins are required
- Possible to use existing tanks to both thicken and digest

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

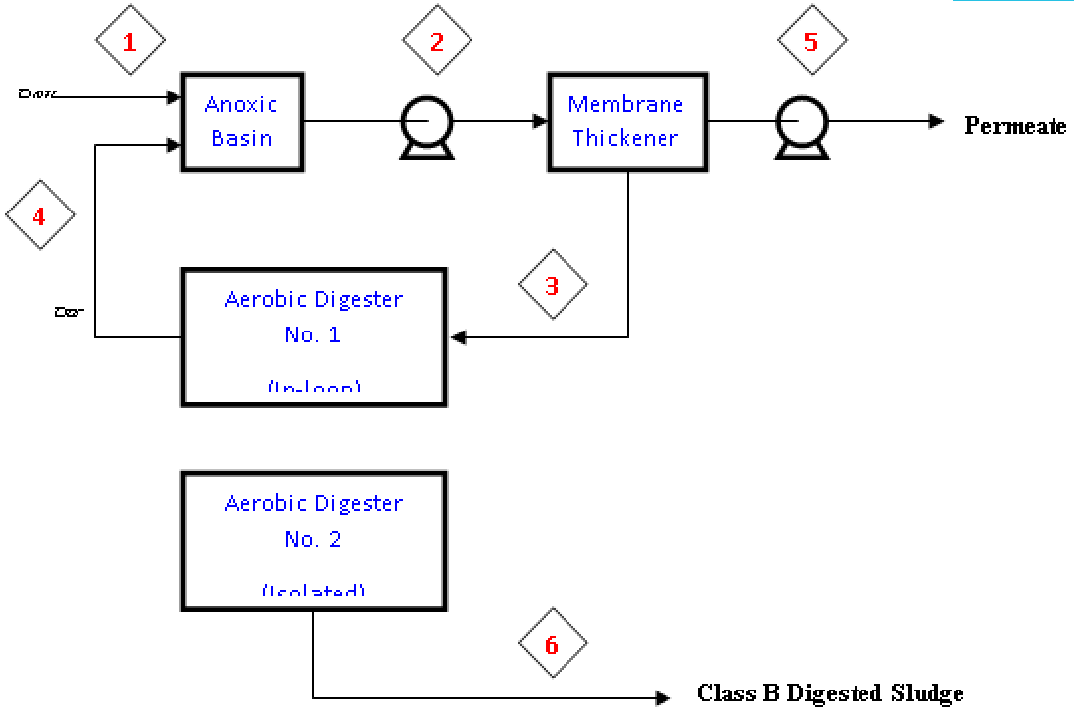
- Two Main Phases
  - In-loop
  - Isolation
- Four Main Basins
  - Two digesters, One premix, one thickener
- Advantages
  - Provides benefits of anoxic/aerobic operation
  - Controls nitrogen and phosphorus in supernatant
- Disadvantages
  - Higher capital cost



Stream ID	Description
1.	Raw sludge and scum from liquid treatment process
2.	Gravity Thickener Influent
3.	Thickened Sludge and Scum airlifted from Gravity Thickener
4.	Nitrified Sludge gravity flowing from In-loop Aerobic Digester
5.	Gravity Thickener Supernatant
6.	Class B Digested Sludge Product

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

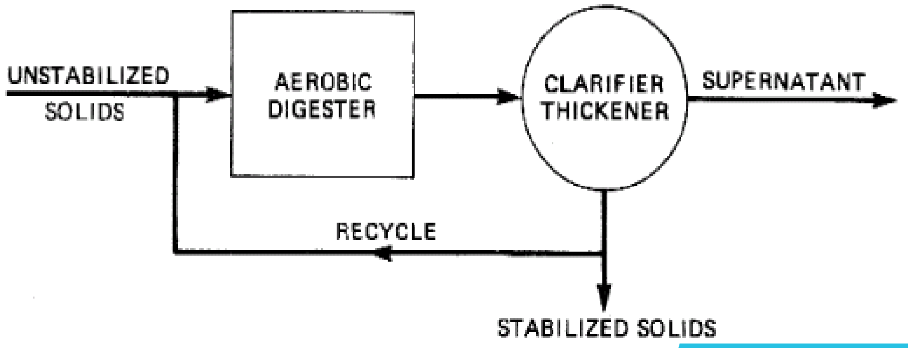
Resembles Activated Sludge Process – Separation/Thickening Downstream of Digestion

Advantages

- Digester operates at fixed level – overflow goes to separator

Disadvantages

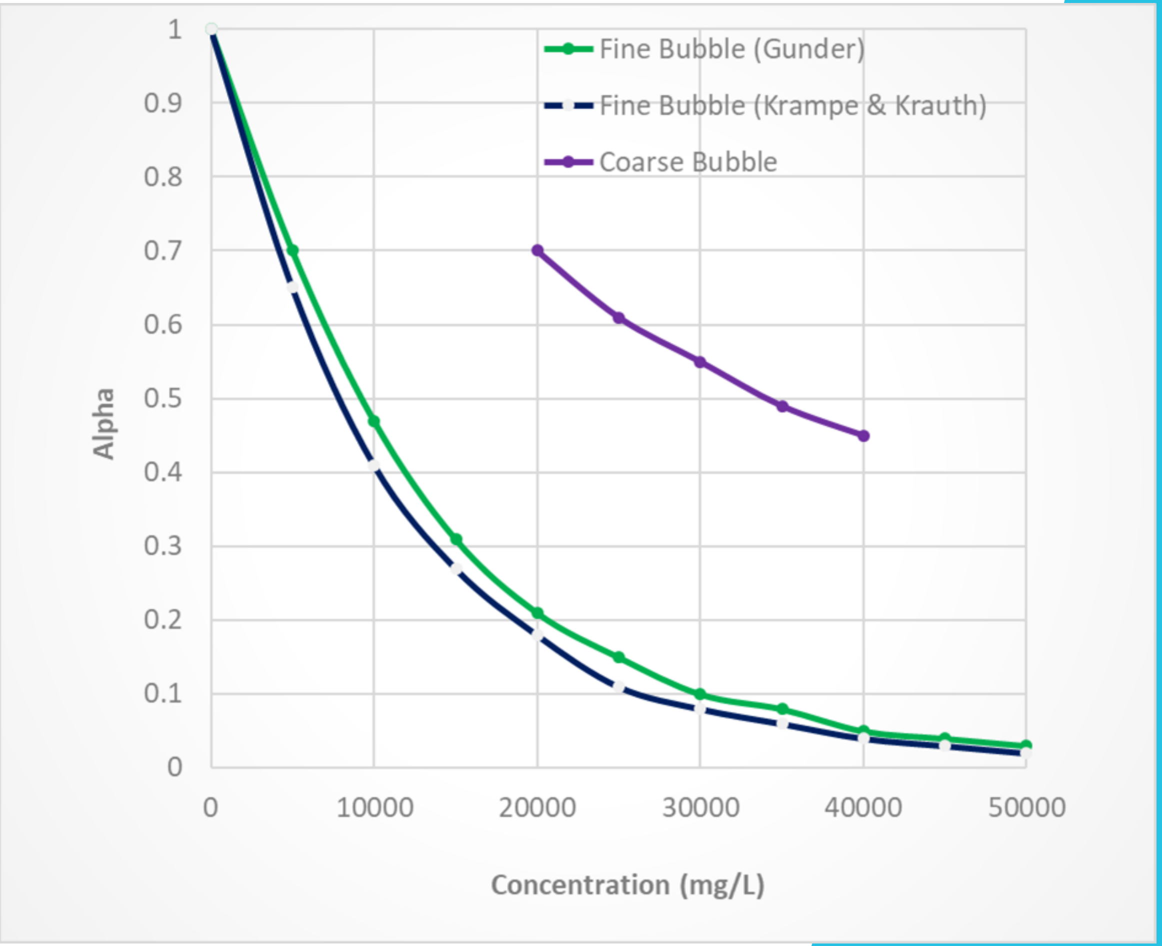
- Digesters sized based on lower solids concentration
- Higher O&M costs
- No control of alkalinity, temperature, nitrogen or phosphorus



Impact of Solids on Aeration

Alpha Factors vs MLSS

- From MBR Research
- Coarse Bubble α 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

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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.

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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

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Thank You!

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