WC: WWOA - Aerobic Digestion Optimization

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How to get 5 lbs of Biosolids out a 10 lb bag of sh*t.

WHAT IS IT?

- Solids handling process where a **<u>LIMITED</u>** supply of oxygen and organics (food) are introduced to microorganisms to facilitate oxidation of organic matter into carbon dioxide and water.
- Microorganisms that get out competed for the limited supply of food use the O2 to consume their own protoplasm. If microorganisms run out of protoplasm to consume they die and become food for other bacteria. This is how volatile solids reduction (VSR) occurs.

Aerobic Digestion Fundamentals

WHAT KIND OF MICROORGANISMS ARE UTILIZED IN AEROBIC DIGESTION?

- **MESOPHILIC FACULTATIVE BACTERIA**: They drive an aerobic digestion process!
- Mesophilic = Microorganisms that thrive in temperatures between 20 C and 37 C
- Facultative = Microorganisms that can live in aerobic (oxygen present), anoxic (no oxygen but nitrates present), and anaerobic (no oxygen or nitrates present) conditions.

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Aerobic Digestion Fundamentals

WHAT KIND OF MICROORGANISMS ARE UTILIZED IN AEROBIC DIGESTION?

- **HETERTROPHIC BACTERIA**: Bacteria that use only organic carbon as a nutrition or energy source to sustain their life. They cannot produce their own food.
- **AUTOTROPHIC BACTERIA**: Bacteria that can use organic carbon but is also capable of using inorganic compounds or light as a nutrition or energy source sustain their life. For example, Nitrifying bacteria are autotrophic bacteria.

Aerobic Digestion Fundamentals - Chemistry
Necessary to Understand How To Optimize the Process

Aerobic Digestion is a biological process similar to Activated Sludge with the exception that…

Activated Sludge (Growth)

Aerobic Digestion (Decay)

Aerobic Digestion Fundamentals - Chemistry

1. Digestion:

$C_5H_7NO_2 + 5O_2 = 4CO_2 + H_2O + (NH_4HCO_3)$

Biomass — Ammonium Carbonate

2. Nitrification:

$NH_4^+ + 2O_2 = H_2O + 2H^+ + NO_3^-$

Ammonia — Acid — Nitrate

3. Digestion with Nitrification:

$C_5H_7NO_2 + 7O_2 = 5CO_2 + 3H_2O + HNO_3$

Biomass — Nitric Acid

Aerobic Digestion Fundamentals - Chemistry

4. Digestion with Nitrification:

$C_5H_7NO_2 + 7O_2 = 5CO_2 + 3H_2O + HNO_3$

Biomass — Nitric Acid

5. Denitrification:

$C_5H_7NO_2 + 4NO_3^- + H_2O = NH_4^+ + 5HCO_3^- + 2N_2$

Biomass — Nitrate — Ammonia — Alkalinity — N Gas

6. Complete Nitrification / Denitrification:

$C_5H_7NO_2 + 5.75O_2 = 5CO_2 + 3.5H_2O + 0.5N_2$

Biomass — N Gas

Aerobic Digestion Fundamentals - Chemistry

18% Oxygen Savings:

3. Digestion with Nitrification:

$C_5H_7NO_2 + \mathbf{7O_2} = 5CO_2 + 3H_2O + HNO_3$

Vs.

6. Complete Nitrification / Denitrification:

$C_5H_7NO_2 + \mathbf{5.75O_2} = 5CO_2 + 3.5H_2O + 0.5N_2$

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Aerobic Digestion Fundamentals - Chemistry

pH Cycle:

1. Digestion: (pH UP, Increase Air if pH > 7.0)

$C_5H_7NO_2 + 5O_2 = 4CO_2 + H_2O + NH_4^+ + HCO_3^-$

2. Nitrification: (pH DOWN, Decrease Air or Air off if pH < 6.3)

$NH_4^+ + 2O_2 = H_2O + 2H^+ + NO_3^-$

4. Denitrification: (pH UP, Turn Air back on once pH ~6.7)

$C_5H_7NO_2 + 4NO_3^- + H_2O = NH_4^+ + 5HCO_3^- + 2N_2$

Why is aerobic digestion process optimization important?

Improved solids management

Reduced Solids Disposal

- Improves digestion by increasing capacity of reactors
- Can improve dewatering operations: reduces polymer, disposal, and run time
- Reduced disposal costs

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Typical Aerobic Digestion System

It's simple
and cheap!!
Just a tank
with diffusers right?

Can you optimize this
to effectively work to achieve
stabilization or solids management
goals?

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Aerobic Digestion Process System
THE HOW

1. Series or Batch Operation
2. Thickening
3. Aerobic & Anoxic Operation
4. Temperature Control
5. Operational Flexibility

The FAB 5

5 Key Techniques
Necessary for Optimum Results

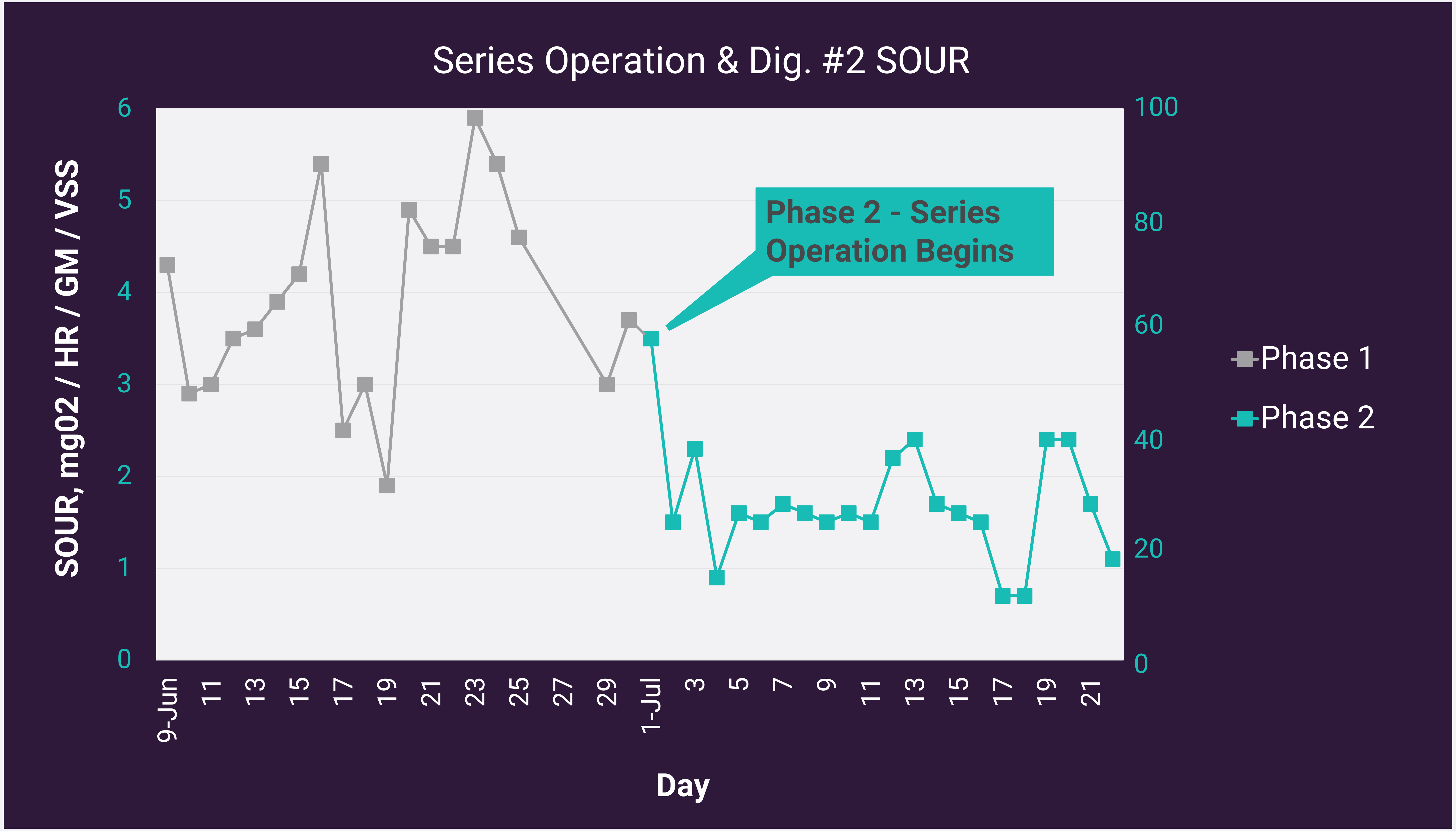
Aerobic Digestion Process System
THE HOW

1. Series or Batch Operation

- Reduces short circuiting of partially digested sludge
- Improved kinetic reactions provide approximately 50% less volume to achieve same volatile solids reduction
- Provides a Time Temp credit of 30%. As a result in Series Operations we can meet the pathogen reduction requirements for Class B with only 42 days at 15°C and 28 days at 20°C

1. Series and Batch Operation – Process Optimization

Clyde, OH WWTP



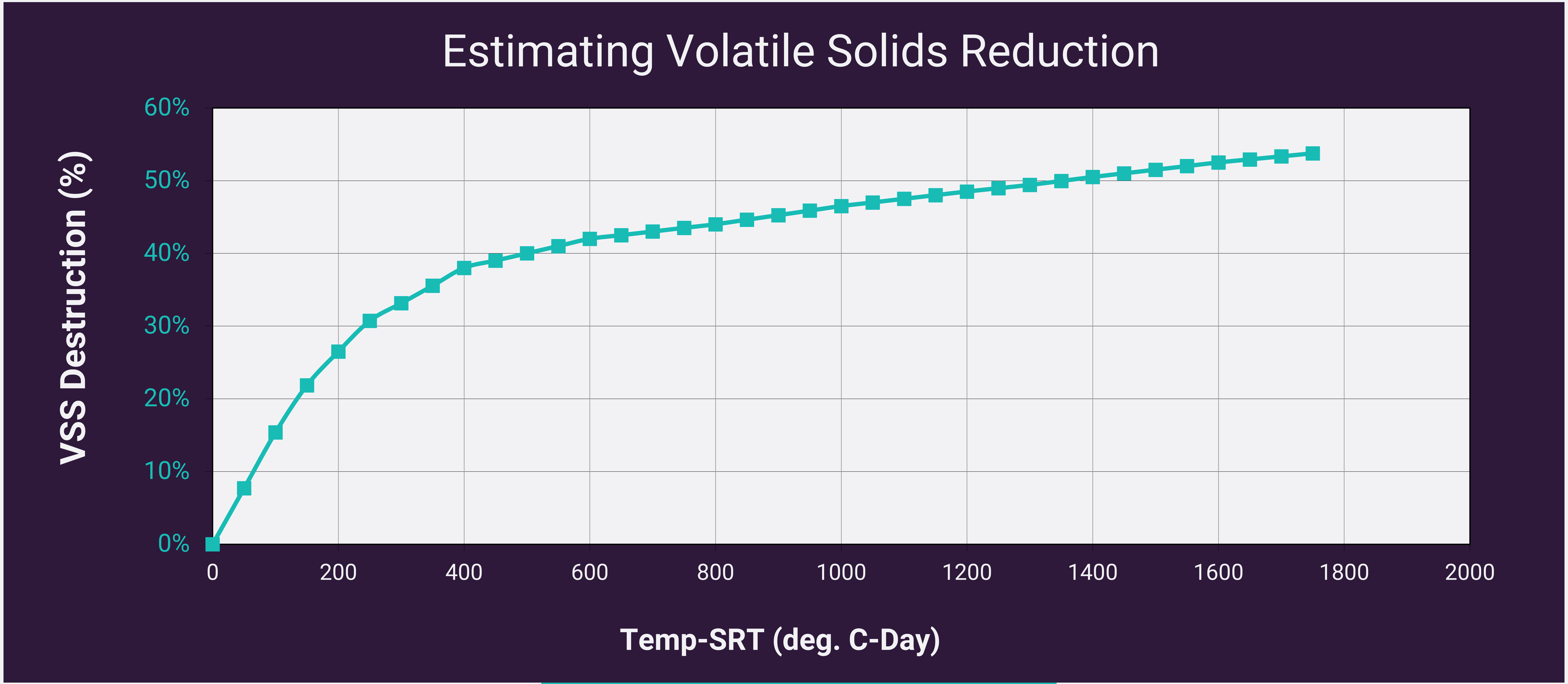
Aerobic Digestion Process System
THE HOW

2. Thickening:

Volatile solids destruction is an exothermic reaction.
Thickening solids retains the heat from VS destruction more effectively

- Smaller sludge volume
- Smaller digesters
- Higher sludge temperatures

2. Thickening – Process Optimization
THE HOW



Ref: WEF MOP No. 8, Vol II, 1992

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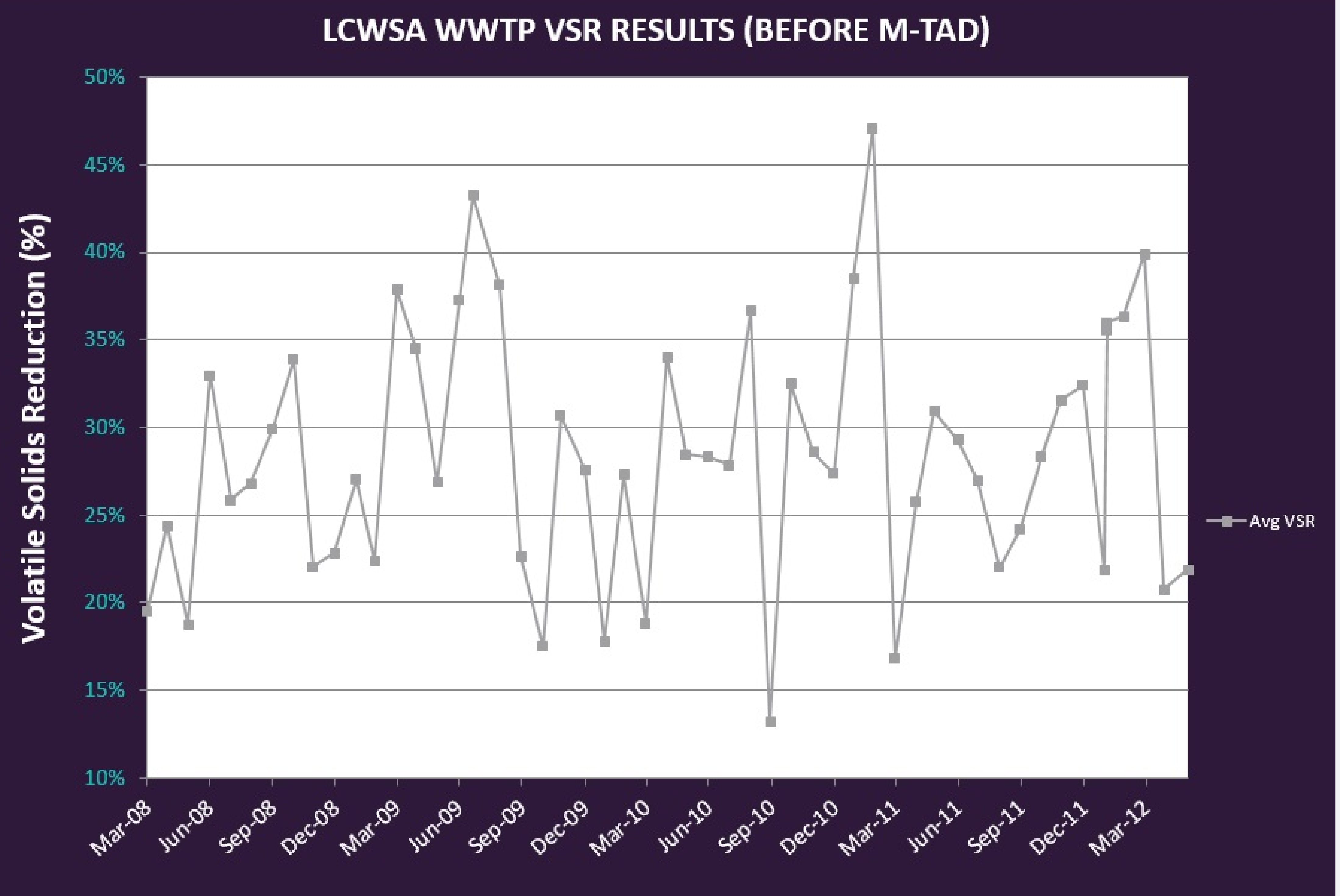
2. Thickening – Process Optimization
Lycoming County, PA WWTP – Results WITHOUT Thickening



- **Unthickened Aerobic Digestion System**
- **Floor Mounted Fine Bubble Diffuser Aeration System**
- **Average VSR of 29%**
- **Solids in Digesters were between 0.5% and 1.5%**

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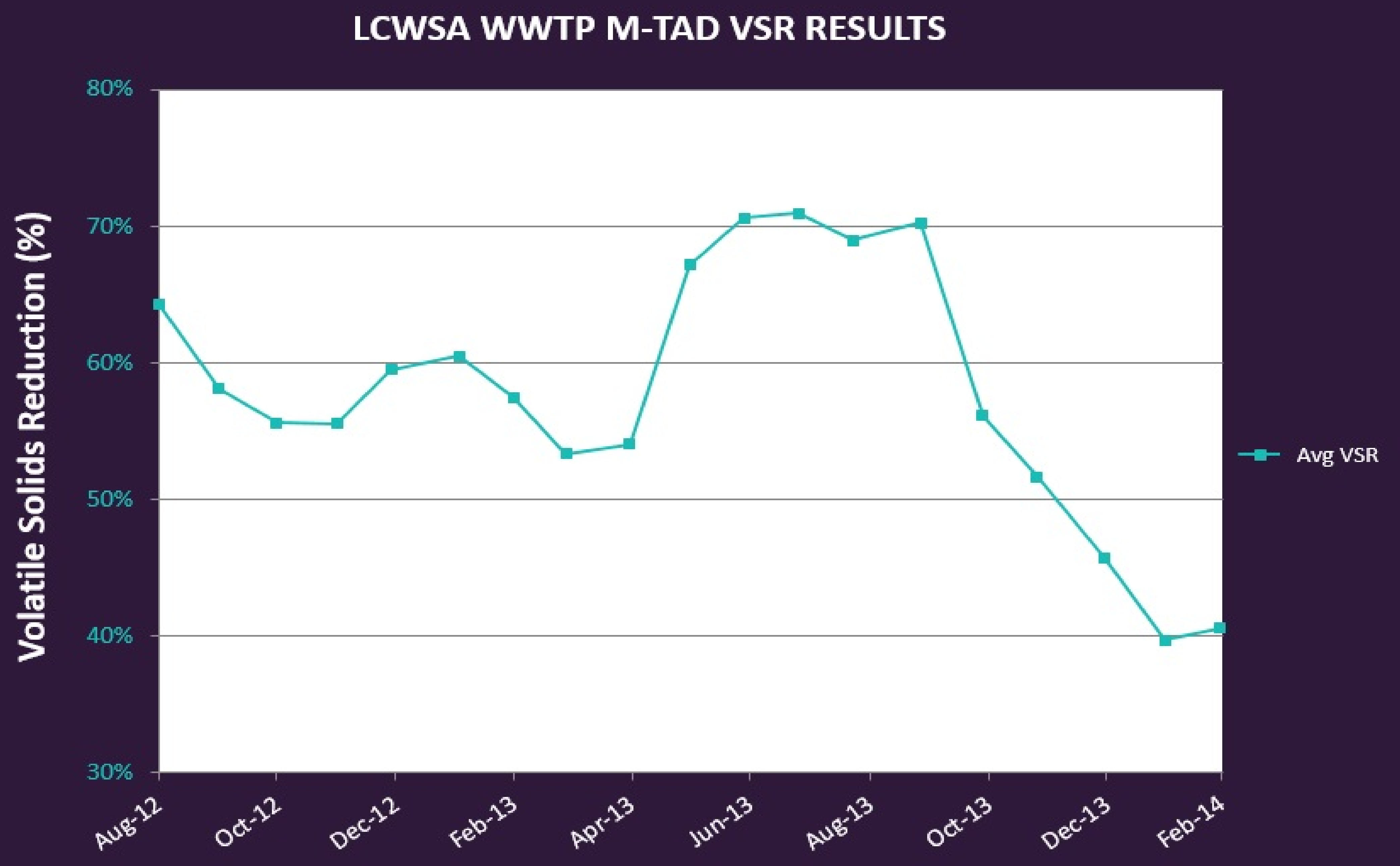
2. Thickening – Process Optimization

Lycoming County, PA WWTP – Results With Thickening



- ✓ **WAS thickened with GBT typically between 4% to 5%**
- ✓ **VSR ranged between 40% and 71%**
- ✓ **More than 50% reduction of dry solids@ $37,000 annual savings on disposal**

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Aerobic Digestion Process System
THE HOW

3. Aerobic and Anoxic Operation

- Reduced total nitrogen
- Preserve alkalinity
- Control odors
- Provides an 18% savings in oxygen requirements
- Plant met/exceeded the Class B requirements

2. Aerobic and Anoxic Operation – Process Optimization

Muncy, PA Facility

Muncy Aerobic Digester Operation Data
(January 2003 – April 2004)

Parameters	Warm Season	Cold Season
Monthly average SRT (days)	29 – 54	32 – 75
Temperature (°C)	22.5 – 30.5	15.5 – 22.5
Dissolved oxygen (mg/L)	0.3 – 2.1	0.5-3.4
VS reduction – Class B $\geq$ 38%	69% – 84%	62% – 84%
SOUR – Class B $\leq$ 1.5 mg/g/hr	0.60	0.62
F. Coliform – Class B $\leq$ 2 million/g TS		80,000
pH range	6.5 – 8.1	6.7 – 7.6
Average alkalinity (mg/L)	79 – 140	100 – 275
Average NH_3-N (mg/L)	**1.1 – 10**	**1.1 – 8.5**
Average NO_3/NO_2-N (mg/L)	**0 – 7**	**0 – 8.5**

- **Customized Aerobic and Anoxic Cycling**
- **Very low NH3-N and NO2-N observed**

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2. Aerobic Digestion – Process Optimization
THE HOW

4. Temperature Control:

Mesophilic bacteria is very sensitive to temperature conditions.

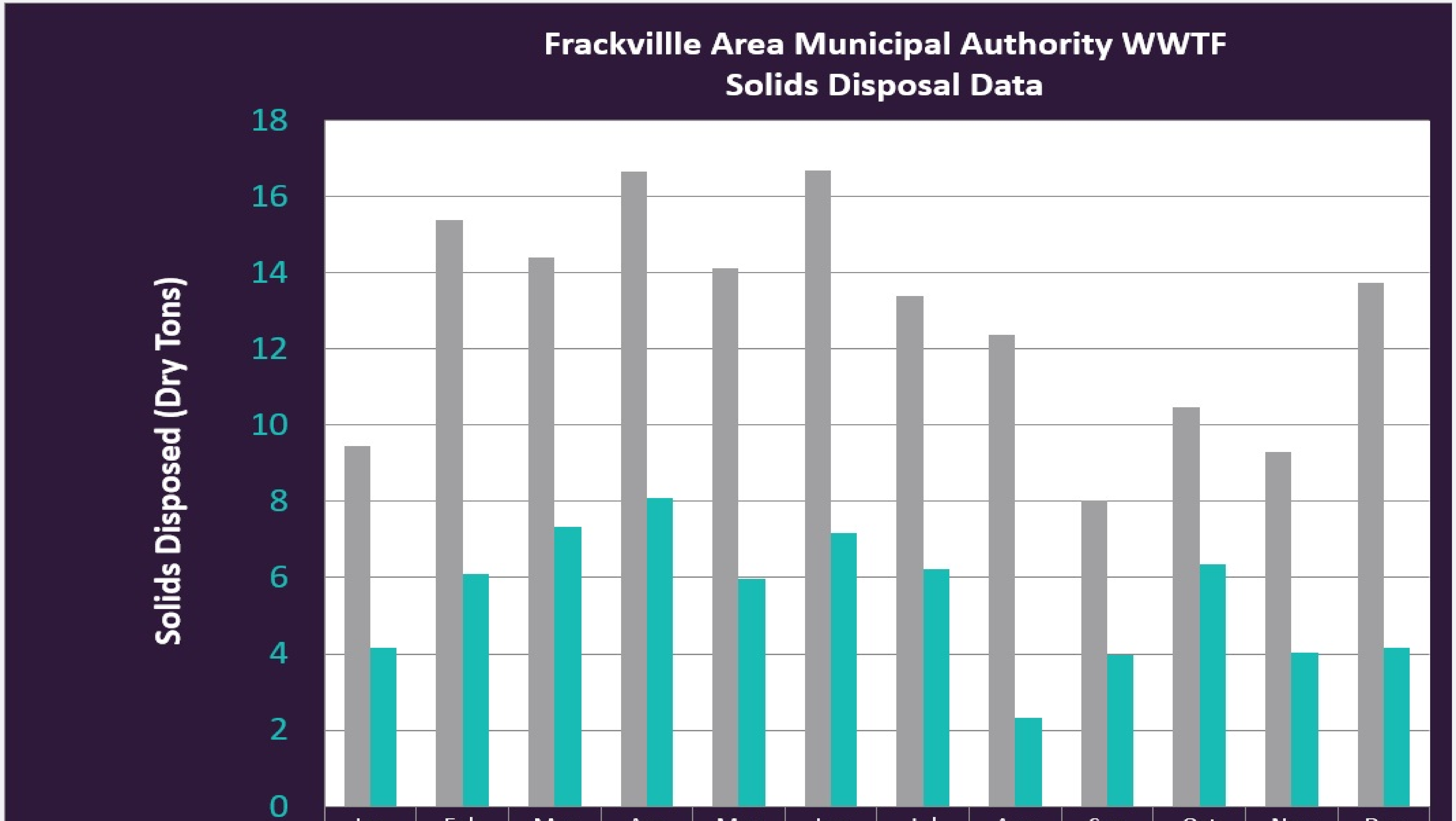
Less then 15^{0}C nitrification and biological activity is hindered.

Temperature greater than 37^{0}C thermophilic bacteria begin to propagate.

- Increased digestion rate
- Consistent operation and performance year round
- Maintain healthy biomass

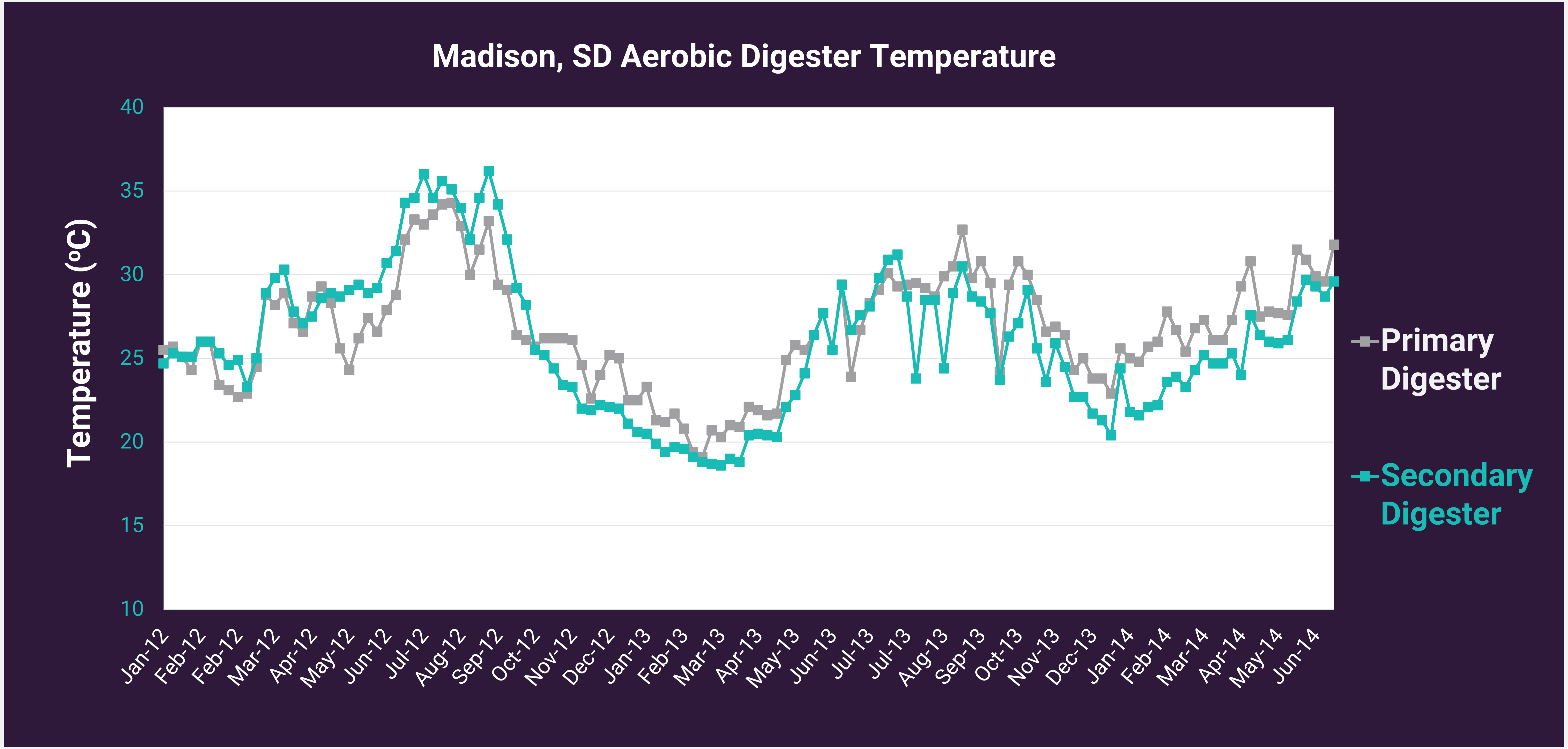
4. Temperature Control – Process Optimization

Frackville, PA Facility – Reduced Solids Disposal

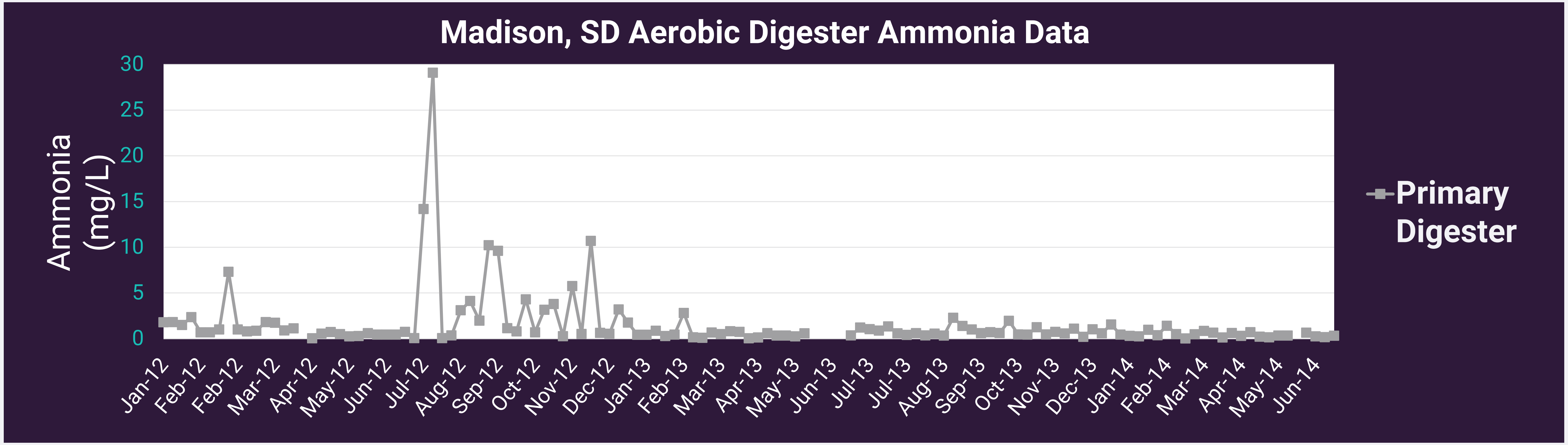


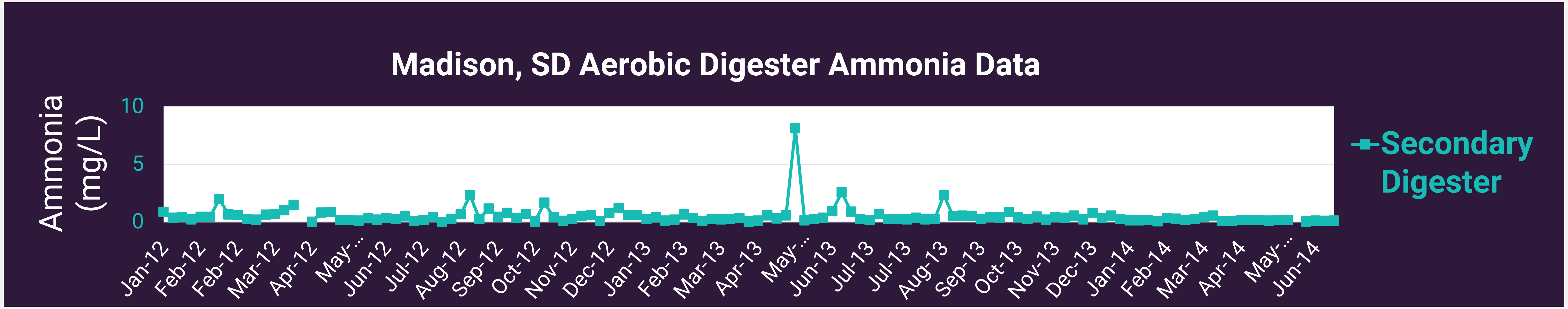
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Before Airbeam System	9.46	15.4	14.41	16.64	14.11	16.68	13.38	12.37	8.03	10.47	9.31	13.74
After Airbeam System	4.16	6.09	7.33	8.10	5.96	7.16	6.24	2.33	3.98	6.36	4.05	4.15

4. Temperature Control – Process Optimization
Madison, SD Facility



4. Temperature Control – Process Optimization
Madison, SD Facility – Nitrification Year Round





Aerobic Digestion – Process Optimization
THE HOW

5. Operational Flexibility

- Ability to monitor pH, T, and DO
- Ability to control sludge thickness
- Ability to control airflow to the digesters

Aerobic Digestion Design
Consequences if These Techniques are Not Followed

INCREASED INSTALLATION AND CAPITAL COSTS:
Larger tanks to meet stabilization requirements

INCREASED DISPOSAL COSTS:
VSR Performance can be limited particularly in cold weather operations

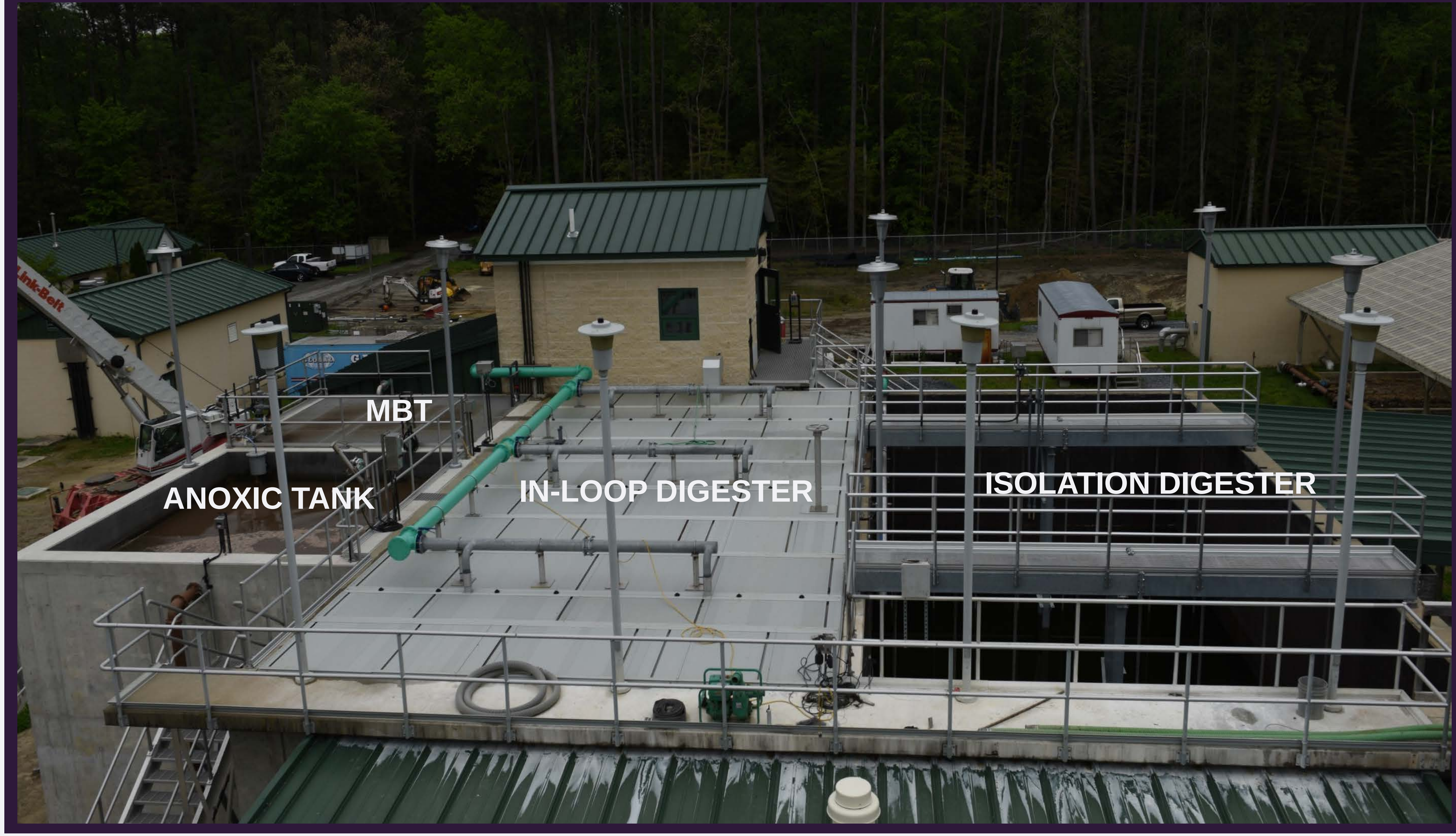
INCREASED ENERGY COSTS:
If you are going to nitrify you mine as well denitrify

AMMONIA TOXICITY AND ODOR:
Since nitrifying bacteria are sensitive to temperature conditions

TN AND TP IMPACT TO MAIN TREATMENT PROCESS:
If no aerobic or anoxic operations TN and TP impact can effect the main treatment process and chemical addition may be required which increases solids loads

Example of the Fab Five

Optimized Aerobic Digestion



1. **SERIES AND BATCH OPERATION:** Two digesters in series
2. **THICKENING:** Membranes used to thicken WAS
3. **AEROBIC/ANOXIC OPERATION:** Anoxic Tank built in to achieve DN
4. **TEMPERATURE CONTROL:** In-Loop Digester is covered
5. **OPERATIONAL FLEXIBILITY:** Pumps on VFDs to control sludge thickness. Blowers on VFDs for added airflow control. Instrumentation to monitor pH, DO, and ORP.