Aerobic Digestion for the 21st Century
Presentation Overview

About Aerobic Digestion
Aerobic Digestion Improvements
Aerobic Digestion in the Real World
Digestion Expertise

MOP 11 Operation of Municipal WWTP

Volume III:
Solids Processes

Chapter 31:
Aerobic Digestion

Author:
Elena Bailey
Digestion Expertise

MOP No. 8 5th Ed., 2009 Design of Municipal WWTPs

Volume III:
Solids Processing and Management
Chapter 25: Stabilization
Section 3: Aerobic Digestion
Author: Miguel Vera
About Aerobic Digestion
What is Aerobic Digestion?

Aerobic Digestion is a process to:

1. Reduce the quantity of sludge for disposal. Bacteria continue metabolism as they do in the liquid process but without new food they use their own biomass (endogenous respiration).

2. Stabilize the sludge so that it is safer for human contact, does not attract vermin (vectors), and odors are reduced.
When is Aerobic Digestion typically used?

1. When it is required by local regulatory agencies
2. When the facility will be land applying their biosolids and needs to meet Class B requirements.
3. When the facility wants to reduce the volume of sludge for final disposal
4. When there are concerns about odors
5. When there is no primary sludge (think BNR)
Pluses and minuses of Aerobic Digestion

Pluses
1. Inherently safer than anaerobic digestion
2. Lower capital cost compared to anaerobic digestion
3. Ease of operation

Minuses
1. Higher energy costs
2. Temperature sensitive
Aerobic Digestion Chemistry

Aerobic Digestion is a **biological process** similar to Activated Sludge.

Activated Sludge = Growth  
Aerobic Digestion = Decay

Process control is required to maintain healthy biomass
Biological Processes

1. Digestion:
\[ C_5H_7NO_2 + 5O_2 = 4CO_2 + H_2O + (NH_4HCO_3) \]
Biomass \hspace{1cm} Ammonium Carbonate

2. Nitrification:
\[ \text{NH}_4^+ + 2O_2 = H_2O + 2H^+ + NO_3^- \]
Ammonia \hspace{0.5cm} Acid \hspace{0.5cm} Nitrate

3. Digestion with Nitrification:
\[ C_5H_7NO_2 + 7O_2 = 5CO_2 + 3H_2O + HNO_3 \]
Biomass \hspace{1cm} Nitric Acid
4. Digestion with Nitrification:
\[ C_5H_7NO_2 + 7O_2 = 5CO_2 + 3H_2O + HNO_3 \]
Biomass \quad \text{Nitric Acid}

5. Denitrification:
\[ C_5H_7NO_2 + 4NO_3^- + H_2O = NH_4^+ + 5HCO_3^- + 2N_2 \]
Biomass \quad \text{Nitrate} \quad \text{Ammonia} \quad \text{N Gas}

6. Complete Nitrification / Denitrification:
\[ C_5H_7NO_2 + 5.75O_2 = 5CO_2 + 3.5H_2O + 0.5N_2 \]
Biomass \quad \text{N Gas}
Factors affecting the rate of digestion:

1. Temperature
2. pH
3. Stability of the sludge
4. Biological diversity
Traditional Digester Design Prior to Class B Requirement

10 – 20 Days SRT (M&E, 1991)

Mixing Air - 30 scfm/1,000 cf

No Performance Requirements
503 Regs Change the Game

Environmental Regulations and Technology

Control of Pathogens and Vector Attraction in Sewage Sludge
Aerobic Digestion – Regulatory Requirements

40 CFR Part 503

1. Class B with respect to Pathogens:
   • 60 Days @ 15 C or 40 Days @ 20 C

   OR

   • Pathogens ≤ 2,000,000 CFU

2. Class B with respect to Vector Attraction Reduction
   • Volatile Solids Reduction ≥ 38%

   OR

   • SOUR ≤ 1.5 mg/L O₂
Aerobic Digestion – Regulatory Requirements (cont.)
Aerobic Digestion Chemistry

18% Oxygen Savings:

3. Digestion with Nitrification:
\[ C_5H_7NO_2 + 7O_2 = 5CO_2 + 3H_2O + HNO_3 \]

Versus

6. Complete Nitrification / Denitrification:
\[ C_5H_7NO_2 + 5.75O_2 = 5CO_2 + 3.5H_2O + 0.5N_2 \]
Aerobic Digestion Chemistry

pH Cycle:

1. Digestion: (pH UP)
   \[ C_5H_7NO_2 + 5O_2 = 4CO_2 + H_2O + NH_4^+ + HCO_3^- \]

2. Nitrification: (pH DOWN)
   \[ NH_4^+ + 2O_2 = H_2O + 2H^+ + NO_3^- \]

4. Denitrification: (pH UP)
   \[ C_5H_7NO_2 + 4NO_3^- + H_2O = NH_4^+ + 5HCO_3^- + 2N_2 \]
Aerobic Digestion Chemistry

Nitrogen Cycle:

1. Digestion:
\[ \text{C}_5\text{H}_7\text{NO}_2 + 5\text{O}_2 = 4\text{CO}_2 + \text{H}_2\text{O} + \text{NH}_4^+ + \text{HCO}_3^- \]

2. Nitrification:
\[ \text{NH}_4^+ + 2\text{O}_2 = \text{H}_2\text{O} + 2\text{H}^+ + \text{NO}_3^- \]

4. Denitrification:
\[ \text{C}_5\text{H}_7\text{NO}_2 + 4\text{NO}_3^- + \text{H}_2\text{O} = \text{NH}_4^+ + 5\text{HCO}_3^- + 2\text{N}_2 \]
Aerobic Digestion Temperature

- Optimum Range: 20°C – 30°C
- Rate (10°C) ≈ ½ Rate (20°C)
- Nitrification stops at ≈ 5°C
Techniques to Improve Process Performance

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

• Reduces short-circuiting of partially digested sludge

• Requires 50% less volume to achieve same volatile solids reduction
Series / Batch Operation

Clyde, OH  2.5 MGD  WWTP
2. Thickening

Advantages:

• Smaller digesters
• Less digested sludge
• Higher sludge temperature
Thickening

Total Digester Solids Concentration

Previous Maximum Concentration = 1.1%

Hauling Cost Savings
- 40%
- 60%
- 60%

Date of Measurement

3. Aerobic / Anoxic Operation

Advantages:

• Reduce $O_2$ requirements by 18%

• Preserve alkalinity

• Reduce total nitrogen
Aerobic / Anoxic Operation

Bellville, TX 0.95 MGD WWTP
Effect of AO/AX on VSR

Ref.: I. Al-Ghusain, et. al., Environmental Technology, Vol. 25, 2004
4. Temperature Control

Advantages:

• Increased digestion rate

• Maintains healthy biomass

• Provides consistent operation and performance year around
Effect of Temp on VSR

Ref.: I. Al-Ghusain, et. al., Environmental Technology, Vol. 25, 2004
5. Flexibility

Designs should incorporate the following as much as possible:

• Ability to control sludge thickness in digesters

• Ability to control air flow to each basin

• Ability to monitor pH, DO, & T
Aerobic Digestion Improvements
Effects of Thickening on Aeration

1. Lowering of alpha values

2. Mixing is as important as aeration

3. Seasonal *thinning* may be necessary
Product Features
Above Water Orificing
Ease of Access
The Diffuser in Action
Improved Mixing Ability
Oxygen Transfer Efficiency

Diffuser Performance Curves
TransMax and MS

Airflow Rate:
15-25 scfm/diffuser
Tank Geometry

Abilities of the single drop diffuser must be kept in mind

1. Oxygen transfer efficiency improves with depth

2. Mixing ability increases with depth as well

3. Varying sidewater depths can be problematic for shear tubes, blowers, and header arrangements
G-TAD Process

G-TAD

stands for:

Gravity Thickened Aerobic Digestion
Gravity Thickener
Aerobic Digester
Working Together
G-TAD Process Flow

1. Waste sludge is pumped into Pre-mix
G-TAD Process Flow

2. Sludge flows into Gravity Thickener
G-TAD Process Flow

3. Thickened sludge airlifted into Digester
4. Nitrified sludge overflows into Pre-mix
G-TAD Process Flow

5. Scum airlifted into Digester

6. Supernatant returned to head of plant
G-TAD Process Flow

1. Pre-Mix
2. Isolated Digester
3. In-Loop Digester
4. Gravity Thickener
5. 6.
6. 7.

7. Class B sludge removed for disposal
## G-TAD Batch Operating Cycle

### DIGESTER #1 CYCLE

<table>
<thead>
<tr>
<th>Feed Stage</th>
<th>Day 1 - 2</th>
<th>Fill Digester #1</th>
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<td>Day 3 - 14</td>
<td>In-loop Thickening</td>
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<table>
<thead>
<tr>
<th>Batch Stage</th>
<th>Day 15 - 26</th>
<th>Isolation</th>
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<td>Day 27 - 28</td>
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### DIGESTER #2 CYCLE

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## G-TAD Installation References

<table>
<thead>
<tr>
<th>Location</th>
<th>Design Flow</th>
<th>Plant Configuration</th>
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<td>Stockbridge, GA</td>
<td>1.5 MGD</td>
<td>SBR</td>
<td>2002</td>
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<td>Belleville, TX</td>
<td>0.95 MGD</td>
<td>Complete Mix</td>
<td>2002</td>
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<td>Clermont, FL</td>
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<td>2002</td>
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<td>Gardner, KS</td>
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<td>2003</td>
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<td>Woodland, WA</td>
<td>1.3 MGD</td>
<td>SBR</td>
<td>2003</td>
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<td>Myrtle Creek, OR</td>
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<td>Oxidation Ditch</td>
<td>2004</td>
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<td>Shelton, WA</td>
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<td>Amherst, OH</td>
<td>6.1 MGD</td>
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<td>Blue Mtn. Lake, PA</td>
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<td>Brenham, TX</td>
<td>3.55 MGD</td>
<td>Complete Mix</td>
<td>2004</td>
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M-TAD Process

M-TAD

stands for:

Mechanical Thickened Aerobic Digestion
The PAD-M process is...

An enhanced digestion process to achieve guaranteed Class B biosolids

- with conventional equipment
- in a reduced volume,
- using less energy.
M-TAD Process

Raw Sludge → Mechanical Thickener → Filtrate

Thickened Sludge

Optional Cover for Temp. Ctrl.

Aerobic Digester No. 1

Aerobic Digester No. 2

Aerobic Digester No. 3

Class B Digested Sludge
Diffusers with Shear Tubes
Diffusers with Draft Tube

MULTI-EDUCTOR DRAFT ASSEMBLY WITH AIR-BRIDGE TUBING
## M-TAD Process

### M-ITAD Installation References

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<tr>
<th>Location</th>
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<th>Thickening Method</th>
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<td>Clyde, OH</td>
<td>1.9</td>
<td>Oxidation Ditch</td>
<td>GBT</td>
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<td>Los Lunas, NM</td>
<td>0.7</td>
<td>Extended Aer.</td>
<td>GBT</td>
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<tr>
<td>Paris, IL</td>
<td>1.4</td>
<td>1° &amp; 2° Sludge</td>
<td>GBT/BFP</td>
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<td>Myrtle Beach, SC</td>
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**Ideal for:**

Larger WWTPs
Conversion of existing anaerobic and holding tanks
Bellefonte M-TAD Process

Rotating Biological Contactor followed by M-TAD Process

Engineer: Nittany Engineering

History:

- Objective was to produce Class B biosolids for land application
- Retrofit of equalization basin into three aerobic digesters in series.
- PAD-M process designed for solids loading increase from 2 MGD to 3.2 MGD.
- Thickening to 4% solids was required to meet Class B criteria without having to build additional tanks at 3.2 MGD flow.
Bellefonte M-TAD Process
Bellefonte M-TAD Process

Longer SRT from thickening complimented by outstanding temperature control results in outstanding VS reduction
### Pathogen Data

<table>
<thead>
<tr>
<th>Rep Number</th>
<th>CFU/Dry Gram</th>
<th>Rep Number</th>
<th>CFU/Dry Gram</th>
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<td>1</td>
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<td>4,715</td>
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<td>934</td>
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<td>2,647</td>
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<td>7</td>
<td>5,048</td>
<td>7</td>
<td>414</td>
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<td>Geometric Mean</td>
<td>956</td>
<td>Geometric Mean</td>
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### Third Quarter 2010

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<tr>
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<td>2,785</td>
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<td>164</td>
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<td>4</td>
<td>976</td>
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<td>269</td>
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<td>602</td>
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<td>&lt;59</td>
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### Fourth Quarter 2010

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<th>CFU/Dry Gram</th>
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<tr>
<td>Geometric Mean</td>
<td>480</td>
<td>Geometric Mean</td>
<td>364</td>
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Mem-TAD Process

Mem-TAD

stands for:

Membrane Thickened Aerobic Digestion
Mem-TAD Process

Combines a Membrane Thickening Tank with two Aerobic Digesters

Guaranteed Class B Biosolids

Capable of between 3% & 5% solids

No polymer required or attention to decanting

Continuous thickening - independent of wasting schedule

Reuse quality permeate
MEMBRANE TECHNOLOGY OVERVIEW
Definitions

FLUX: The rate of filtration per unit area of membrane material is called flux.

TMP: The pressure difference across a membrane during filtration is called transmembrane pressure (TMP).

PERMEABILITY: The ratio of flux to TMP is referred to as permeability.
Pressure when permeate suspended
- Pressure when permeating time
- Head loss in piping (Friction, fittings, etc)

= TMP
Membrane Cartridges

Chlorinated Polyethylene membrane; ultrasonically welded to both sides of an ABS plate
Membrane Thickener Data

- Nominal pore size 0.4 micron, effective pore size 0.1 micron
- Effective filtration area 8.6 ft$^2$ to 15.1 ft$^2$ per cartridge
- MBT Design flux 5 gfd @ 20° C
- MBT Cross flow velocity is 2.25 ft / sec
Submerged Membrane Unit (SMU)
Physical Responsibility
Design of The Submerged Membrane Unit (SMU)

 Acts like an air lift pump
  • Continuous Course bubbles at the bottom
  • Fully enclosed
  • Air scour in constant contact with membrane through full range of travel
  • Continuous movement of mixed liquor, keeps tank contents well mixed and in suspension
Biofilm - Basics

All submerged membranes have a biofilm.

What is a biofilm?
• A complex dynamic matrices comprised of microorganisms, EPS/SMP, non-biological solids, substrates, metabolites, interior pores and channels

What do biofilms do?
• Create a dense secondary membrane that can allow for enhanced nutrient removal and degradation of refractory organics

Why do we care?
• Biofilms serve as the primary filter and represent a changing resistance to filtrate flow (affects plant ops.)
Biofilm Conditions

- Ideal
- Stable TMP

- Non-Uniform
- High TMP

Increased TMP Variable TMP Stable TMP High TMP
The Biofilm (A Dynamic Membrane)

- Serves as primary filtering mechanism (0.1 μm)
- Biofilm control is key to membrane performance in mixed liquor (*biohydraulics*)
Types of Membrane Fouling

- Adsorption
- Pore clogging
- Particle deposition

A: macromolecules on membrane matrix
B: macromolecules (aggregates) and cell debris
C: not serious if cells alone; serious w/ interstices filled by EPS (Extracellular Polymeric Substances)
Biofouling
In UF Membranes (Choi et. al., 2005)
Biofilm Management

Air Scouring

• The rise velocity of bubbles impacts shear force and boundary layer thickness
• Rise velocity is a function of flowrate, geometry and flow resistance
• Intensity requirement is a function of deposition rate (flux) and fluid viscosity
• Defined air flow pathways promote even distribution
• Turbulent velocity (slug flow) maximizes effect
Air Scour
How does SMU Air Scour work?

Continuous cross-flow of mixed liquor and air maintains optimum biofilm thickness
Chemical Cleaning (CIP)

Maintenance Cleaning
- Intended to remove surface (biofilm or cake) fouling.\(^1\)
- Does not involve taking tanks out of service for extended periods of time (~1-4hr)
- Routine procedure
- Can return to MBR filtration mode in ~15 minutes

Recovery Cleaning
- Intended to “dislodge particles from membrane microstructure.”\(^1\)
- May take from >4-24hrs·
- Requires that membranes be soaked in concentrated chemical solution·
- Generally a non-routine procedure

\(^1\) Membrane Systems for Wastewater Treatment, WEF 2006.
Enviroquip utilizes Maintenance Cleaning only (no Recovery Cleaning) to address *irreversible fouling*.

Operating at low TMP minimizes deep pore fouling and extends membrane service life.

High concentration, frequent dosing can impact sludge quality and increases TDS, making effluent less suitable as RO feed.

Minimizing chemical exposure minimizes membrane deterioration and extends membrane service life.

Reducing downtime also reduces owner risk while improving system flexibility.
Enviroquip Maintenance Clean

Diagram showing:
- Pressure Regulator
- Chemical Eductor
- Flowmeter
- Control Valve
- Stock Chemical Supply
CIP Cartridge Distribution

- Cleaning takes approximately 2-4 hour / MBR basin, using a dilute solution of 0.5% Sodium Hypochlorite or Citric Acid
- In-situ cleaning of membranes without draining MLSS
- Chlorine dosage less than that typically used for filamentous microorganism control
- No tank liners required
Relaxation
(King County DNR EW200 Pilot)

Sample Date: 10/11/05
Avg. Gross Flux = 16.3 gfd
Air Scour = 0.014 SCFM/ft²
Minimum Maintenance Of Membrane Thickener

- Automated Diffuser Cleaning, approx. 30 min/day
- Membrane Relax, approx. 1min/10min
- Chemical Cleaning, in-situ clean every 6 months, approx 2 hour duration

NO NEED TO DRAIN TANKS OR TAKE OUT OF SERVICE FOR CHEMICAL CLEANING!
Mem-TAD Process
SHOW ME THE BENEFITS

Case Studies of Aerobic Digestion Processes with Membrane Thickening
Dundee WWTP, Michigan

MBR and Mem-TAD
Dundee WWTP, Michigan

Engineer: Arcadis

History:

- Objective was to reduce the hauling to 2 times per year. Tanks are designed to store 180 days at 3% solids.
- Operator friendly when compared to other systems.
- Enviroquip’s Aerobic Digestion experience rated higher when evaluated against other vendors/technologies.
Membrane Thickener Tank
Digester 1
Digester 2
Dundee WWTP, Michigan

Thickening Performance

Sep & Oct 2005 Operation

% solids vs. Date

- WAS
- MBT Thickener
- Digester #1
- Digester #2
Dundee WWTP, Michigan

MBT Permeate Results

- BOD
- TSS
- NH3

9/5 9/15 9/25 10/5 10/15
January 2007 to June 2008 Data

Sustainable Permeate Quality
before it’s blended with MBR effluent

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
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<td>BOD:</td>
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<tr>
<td>TSS:</td>
<td>2.00 mg/l</td>
</tr>
<tr>
<td>NH₃-N:</td>
<td>0.22 mg/l</td>
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<td>NO₃-N:</td>
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<tr>
<td>TP:</td>
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Dundee WWTP, Michigan Sludge Hauling Cost Summary

<table>
<thead>
<tr>
<th>Years</th>
<th>Gallons Hauled</th>
<th>Dry Tons</th>
<th>Yearly Cost</th>
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<tbody>
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<td></td>
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<td>Belt</td>
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<tr>
<td>2004 (0.6 MGD SBR)</td>
<td>248,885 – Belt</td>
<td>22.67 – Belt</td>
<td>$16,850</td>
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<td>943,200 – Truck</td>
<td>99.39 – Truck</td>
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<td>1,192,100 - Total</td>
<td>122.06 - Total</td>
<td>$46,938 - Total</td>
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<td>2005 (1.2 MGD MBR)</td>
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<td>55.62 – Belt</td>
<td>$39,135 – Belt</td>
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<td>MBT operational for 2nd half of year only</td>
<td>432,000 – MBT</td>
<td>47.55 – MBT</td>
<td>$14,623 – MBT</td>
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<td>1,004,400 - Total</td>
<td>103.17 - Total</td>
<td>$53,758 – Total</td>
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<td>2006</td>
<td>887,400 - MBT</td>
<td>130.48 – MBT*</td>
<td>$32,739 - MBT</td>
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Belt press was needed for years 2003 -05 due to lack of storage space.

Sludge Hauling costs for first full year of operation of MBT in 2006 was $32,739 which is lower than the last 5 years.
McFarland Creek, OH
MBR + Mem-TAD
SMUs Installed Directly in Digesters
Membrane thickening at McFarland Creek WWTP was able to thicken up to 5% solids.
Union Rome WWTP, Ohio
Engineer: CT Consultants

MBR and Mem-TAD
The TS concentration was MORE THAN TRIPLLED by thickening with membranes at Union Rome WWTP.
Union Rome WWTP, Ohio

January 2010 to October 2010 Data

**Sustainable Permeate Quality**
after it’s blended with MBR effluent

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tr>
<td>BOD:</td>
<td>&lt;1.0 mg/l</td>
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<tr>
<td>TSS:</td>
<td>&lt;1.0 mg/l</td>
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<tr>
<td>NH₃-N:</td>
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<td>TP:</td>
<td>&lt;5.0 mg/l</td>
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Membrane Thickening

Combines a Membrane Thickening Tank with a Solids Holding Tank.

Thickening not Class B!

Capable of between 3% & 5% solids

No polymer required

Continuous thickening - independent of wasting schedule
Membrane Thickening Process Flow Diagram
Woodside NY – 0.30 MGD

**Driver:** Reduce Hauling costs

Retrofit system following Conventional Activated Sludge

Operational since Feb. 2008

Using Existing Tanks (2-25’ dia. x 15’ deep)
Woodside, NY
Woodside MBT Compartment / SHT
Woodside, NY Results

Thickening of CAS solids to 3.0 to 3.5%

Reduced the number of trucks by Half in 2008
Reduced amount of Nitrogen in the sludge and permeate

Low operator attendance required
Eco-MAT
Operations: What don’t you do?

Start the unit up each day

Shut the unit down each day

Check the polymer system

Check the unit repeatedly throughout the day

Check the polymer system
Operations: What do you do?

Collect daily process data

Perform visual inspection of system

Chemical clean membranes 3 – 4 times per year

Perform regularly scheduled preventative maintenance
## MBT – Aerobic Dig. Installations

<table>
<thead>
<tr>
<th>Date</th>
<th>Plant</th>
<th>City</th>
<th>State</th>
<th>Liquid Process</th>
<th>MBT/ PAD-K</th>
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</tbody>
</table>
AirBeam Covers

AirBeam® covers help to aid in temperature control and integrates Ovivo’s aeration equipment.
AirBeam with Diffusers
AirBeam Covers

AirBeam Components
AirBeam Covers
Is Aerobic Digestion Right for You
Right for You?

Aerobic Digestion is very good for anyone who has a nutrient limit on their effluent.

We are able to remove nitrogen (and phosphorus with the mem-TAD) thus lowering the impact of recycle streams on the liquid process.

Mem-TAD systems can be fed around the clock, this means less of a shock on the liquid stream biomass.
Right for You?

Our products and systems (especially the membranes) are ideal for expanding existing capacity of treatment plants.

This is a huge issue as towns and cities have to do more with less all the time.
Right for You?

Membrane products produce reuse quality effluent
As water becomes more and more valuable this feature is going to become more and more important for wastewater plants
Right for You?

Coarse bubble diffusers work extremely well in deep tanks, always be on the lookout for a plant that has existing deep tanks and/or one looking to lower it’s blower power requirements.
Thank You for your Time and Attention!