New Techniques for Anaerobic Digestion of Municipal Solid Waste

Compost Council of Canada
21st Annual National Compost Conference
Charlottetown, PEI
September 19-21, 2011

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What Is Anaerobic Digestion (AD)?

AD is biotechnological process to convert organic matter (waste) into fuel (methane rich biogas) and then converted into energy (biogas utilization).

- **Hydrolysis** of the input materials breaks down insoluble organics into simple sugars which are available for other bacteria.
- **Acidogenic and acetogenic bacteria** degrade the sugars into mainly organic and acetic acids.
- **Methanogenic bacteria** convert these products to methane and carbon dioxide.

Benefits of AD:

1) Efficient means of waste treatment and volatile solids conversion/reduction

2) Produces recoverable energy

3) ‘Green’ approach
Where is AD used?

Liquid Wastes

- Industrial Waste/wastewater (e.g., food processing, biofuels, etc)

Semi-solid & Slurry Wastes

- Source separated Organics (SSO) MSW
- Industrial Agricultural
Anaerobic membrane bioreactor (AnMBR) is a form of high-rate anaerobic digestion (AD) technology. It creates two valuable outputs:

1. Renewable energy source in the form of biogas (methane) which can displace natural gas or be used for electrical generation
2. High quality, solids-free anaerobic effluent

Excellent AD technology for highly concentrated (high COD/TSS/FOG) wastes. Typical organic loading rates of 6-10 kg COD/m³·d; complete retention of biomass allows for higher loadings and process stability. Experienced technology; full-scale systems since 2000, full-scale tests since 1990’s.
Anaerobic Membrane Bioreactor (AnMBR) Process
Comparison of Anaerobic Digestion Processes

Conventional Anaerobic System
HRT = SRT

Anaerobic MBR (AnMBR) System
SRT >> HRT
= better digestion, more biogas!!
Submerged Membrane Unit Technology

- Manifold
- Tube
- Membrane case
- Membrane cartridge
- Diffuser case
- Diffuser
Membrane units installed in a tank

Anaerobic membrane tanks are completely covered/sealed to:

1. Maintain anaerobic conditions
2. Prevent odors
3. Collect biogas
AnMBR Technology – Process Advantages

1. **Small footprint.** Operates at higher organic loading rates; minimizes reactor size and footprint.

2. **Complete retention of biomass (by use of membranes).** Assurance of consistent high degree of digestion with superior process stability.

3. **VSS and FOG is readily digested.** Simplifies overall system, increases biogas yield and reduces costs.

4. **Maximizes biogas (methane) production.** Due to longer solids retention (SRT) and complete-mix conditions in a ‘wet’ anaerobic environment, biogas production is maximized.

5. ** Produces stable and valuable digestate streams.** AnMBR solids-free effluent can be easily discharged to POTW and liquid or dewatered sludge has excellent fertilizer or soil additive value.

6. **Thermophilic temperature operation and stable process (no solids loss).** Better solids digestion, higher bacterial rates, higher biogas yield, less new bios, Class A type sludge (pathogen destruction).
17 operating AnMBR full-scale plants in Japan and 1 in USA:

- Distillery stillage (sweet potatoes, barley, rice)
- Food processing wastes (confectionery, beverage, candy, prepared meals, sauces, etc)
- Potato processing
- Alcohol/ethanol production
- Septage
- MSW (source separated food wastes) x 2
Nishi-Tenboku Sanitation Center, Hokkaido, Japan

Municipal Solid Waste Digested in an AnMBR to Produce ‘Green Energy’ and Treated Effluent

Example Installation
### Processing Capacity/Methods

<table>
<thead>
<tr>
<th>Raw Sewage (Aerobic MBR with N removal)</th>
<th>Raw sewage</th>
<th>14 kL/d (4000 gpd)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Septic sludge</td>
<td>5 kL/d</td>
<td>(1400 gpd)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>20 kL/d</strong></td>
<td><strong>(5500 gpd)</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Organic Waste Throughput (AnMBR)</th>
<th>MSW</th>
<th>6 ton/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewage sludge / WAS</td>
<td>3 ton/d</td>
<td></td>
</tr>
</tbody>
</table>

- December 2002 - AnMBR system operational and digesting MSW
- Waste sludge from downstream aerobic MBR process also digested in AnMBR
- Process operates at thermophilic condition (55°C (135°F)) to maximize digestion and biogas production
Waste streams to AnMBR facility:

1. Waste activated sludge from nearby POTW (3 ton/d)

2. Municipal MSW (source separated food waste) (6 ton/d)

The MSW is anaerobically digested for energy generation; high energy substrate:
- 250,000 mg/l COD
- 20% TS (up to 20% as impurities)
Basic process:

1. Break open bags to expose substrate and inorganic material
2. Mix received waste and inject steam to pre-heat the substrate
3. Solubilize waste, remove remaining inorganic materials with a screw press
4. Anaerobic digestion via AnMBR process
5. Convey, treat, and utilize biogas
6. Polish AnMBR permeate in aerobic MBR then direct discharge in waterway
7. Process waste sludge and reclaim as soil additive
Crush/bag separator
(breaks open and removes bags)

Mix separator
(solubilization + inorganics removal)

Screw Press
(removes large particles and inorganics)
• Anaerobic reactor operates at thermophilic temperature (55 °C)

• Biogas is utilized to heat reactor, buildings at the facility (boiler) and incinerator
Anaerobic sludge is dewatered/dried, bagged and used as soil additive.
Biogas sent to gas holder, treated for $\text{H}_2\text{S}$, then utilized as fuel for heating/incineration.
AnMBR Process Design Results at Hokkaido, Japan

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature (°C)</td>
<td>54</td>
</tr>
<tr>
<td>Hydraulic Retention Time, HRT (d)</td>
<td>15</td>
</tr>
<tr>
<td>Solids Retention Time, SRT (d)</td>
<td>25-30</td>
</tr>
<tr>
<td>COD load (kg/d)</td>
<td>1,200</td>
</tr>
<tr>
<td>COD loading rate (kg/m³·d)</td>
<td>7.0</td>
</tr>
<tr>
<td>Biogas Production (m³/d)</td>
<td>700</td>
</tr>
<tr>
<td>Biogas CH₄ (%)</td>
<td>72</td>
</tr>
<tr>
<td>Biogas H₂S (ppm)**</td>
<td>15</td>
</tr>
<tr>
<td>AnMBR Sludge (% TS)</td>
<td>5.0</td>
</tr>
<tr>
<td>AnMBR NH₃-N (mg/l)</td>
<td>&lt; 2500</td>
</tr>
<tr>
<td>AnMBR Eff COD (mg/l)</td>
<td>&lt; 2000</td>
</tr>
<tr>
<td>AnMBR Eff TSS (mg/l)</td>
<td>&lt; 2</td>
</tr>
</tbody>
</table>

AnMBR Effluent
- 4.5% TS
- ~70% Volatility
- < 1000 mg/l BOD
- < 1 mg/l TSS

AnMBR Sludge
- 4.5% TS
- ~70% Volatility
- 5.0% TS
- < 2500 mg/l NH₃-N
- < 2000 mg/l COD
- < 2 mg/l TSS
Annual Average Operational Results (Mass Balance)

<table>
<thead>
<tr>
<th>AnMBR Process Feed</th>
<th>Feeding</th>
<th>MSW</th>
<th>1,935 ton</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Waste sludge</td>
<td>3,868 ton</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total (wet)</td>
<td>5,803 ton</td>
<td></td>
</tr>
<tr>
<td>TS</td>
<td>MSW</td>
<td>290 ton</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Waste sludge</td>
<td>102 ton</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total (dry)</td>
<td>392 ton</td>
<td></td>
</tr>
<tr>
<td>TCOD</td>
<td>MSW</td>
<td>366 ton</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Waste sludge</td>
<td>52 ton</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>418 ton</td>
<td></td>
</tr>
</tbody>
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* MSW is mixed with AnMBR sludge

<table>
<thead>
<tr>
<th>Biogas*</th>
<th>Generated gas</th>
<th>185,000 m³</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CH₄ concentration</td>
<td>72%</td>
</tr>
<tr>
<td></td>
<td>CH₄ available</td>
<td>133,000 m³</td>
</tr>
<tr>
<td></td>
<td>H₂S concentration</td>
<td>15 ppm</td>
</tr>
<tr>
<td>* After biogas treatment</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Waste Sludge from AnMBR</th>
<th>Waste Sludge</th>
<th>3,422 ton (wet)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TS</td>
<td>5.0 % solids</td>
</tr>
<tr>
<td></td>
<td>TCOD</td>
<td>81 ton</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Overall Removal/Volume Reduction</th>
<th>TS reduction</th>
<th>70-75%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TCODₜₜ removal</td>
<td>77-83%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dewatered Sludge</th>
<th>Dried sludge</th>
<th>120 ton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incinerated ash</td>
<td>20 ton</td>
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</tbody>
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Conclusions

- AnMBR technology efficiently anaerobically digests food waste to:
  - produce a source of renewable energy,
  - valuable digestate product, and
  - dischargeable effluent all under complete anaerobic conditions

- Two AnMBR’s continue to operate at food waste recycling centers in Japan
  - stable operation at thermophilic conditions, without toxicity and performance concerns
  - provides high (80%+) COD removal, 70%+ TS destruction, and efficient biogas production

- ADI-AnMBR technology has great market potential in North America for food waste digestion
  - divert food waste from landfill (saves $$ and regulation driven)
  - ‘green’ and sustainable approach / reduce in greenhouse gas emissions
  - generate renewable energy (biogas to electricity) and biofertilizer