Biologically Enhanced Primary Treatment

Ohio WEA 2018

TRANSFORMING WATER. ENRICHING LIFE.
Columbus, OH Fun Facts

• 50% of the American population lives within how many miles of Columbus?...

• 500 miles

• Columbus was the very first site of this type of school in the nation........

• Junior High, Graham Expeditionary School in Indianola which is a charter school today.

• Columbus was the site of the world’s first water filtration facility designed by Clearance and Charles Hoover. Same design and treatment protocols are still in use today.
The Wastewater Treatment Plant of Today

Screening → Primary Settlement → Activated Sludge → Nutrient Recovery → Final Effluent

Thickening → Pre-treatment → Anaerobic Digestion → Dewatering → Biosolids to land

Energy Recovery

19th Century

20th Century
The Wastewater Treatment Plant of Today

Screening 1872 → Primary Settlement 1858 → Activated Sludge 1914 → Nutrient Recovery 1857 → Final Effluent

Thickening 1955 → Pre-treatment 1976 → Anaerobic Digestion 1895 → Dewatering 1857 → Biosolids to land 1860

19th Century → Energy Recovery ??? → 20th Century
Wastewater Treatment Evolution Timeline

1846 1854 1857 1858 1859 1863 1867
Liming Activated Carbon Filter press dewatering Primary settlement, electricity Thermal drying Freezing Struvite precipitation

1895 1887 1880s 1872 1871
Septic tanks Anaerobic sand filter Interest in anaerobic digestion Screening and thermal drying Ammonium recovery

1914 1965s 1970s 1980 1990s
Activated Sludge Thermal hydrolysis Upflow Anaerobic Anaerobic fluidized bed MBR
Issues With Use of Technology Designed to Meet 19th Century Drivers

- We rely on activated sludge and variants
- Produces secondary sludge which doesn’t digest well
- We still design digestion facilities which are sub-optimal
- Current best practices is to build new plants which already need pre-treatment bolt-on to improve performance
- They are not designed for modern drivers
Industry Evolution

No Centralized Treatment
Storage Lagoons
Primary Treatment
Biological Filters
Activated Sludge
Nutrient Removal
Resource Recovery?
Advanced Primary Treatment
Evolution

- Chemically-Enhanced Sedimentation
- Mechanically Enhanced Separation
- Ballast Enhanced Sedimentation
- Biologically Enhanced Treatment
CARBON (BOD) EXPLAINED

Typical domestic BOD fraction:
- 55% sBOD
- 31% ffBOD
- 24% sBOD
- 45% pBOD

(Guellil, et. al. 2001)
Key Mechanisms: Biosorption & Bioflocculation

Total BOD
Raw WW

- True Soluble
- Colloidal
- Particulate

Uptake
Coagulation
Enmeshment

Biological floc (WAS)
- Microorganisms
- Biopolymers (EPS)

Contact Tank: Short HRT and Mild Aeration
<table>
<thead>
<tr>
<th>PRIMARY TREATMENT</th>
<th>BOD FRACTION REMOVED</th>
<th>REMOVAL MECHANISM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Conventional</strong> Primary Clarification</td>
<td>✓ Particulate/settleable</td>
<td>Sedimentation.</td>
</tr>
<tr>
<td></td>
<td>✓ Colloidal</td>
<td></td>
</tr>
<tr>
<td><strong>Chemically Enhanced</strong> Primary Clarification</td>
<td>✓ Particulate/settleable</td>
<td>Sedimentation with chemical coagulation and flocculation.</td>
</tr>
<tr>
<td></td>
<td>✓ Colloidal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ Colloidal</td>
<td></td>
</tr>
<tr>
<td><strong>Mechanically Enhanced</strong> Microscreens &amp; Filters</td>
<td>✓ Particulate larger than filtering media</td>
<td>Physical barrier. Mechanical separation.</td>
</tr>
<tr>
<td></td>
<td>✓ Colloidal</td>
<td></td>
</tr>
<tr>
<td><strong>Ballast Enhanced</strong> Primary Clarification</td>
<td>✓ Particulate/settleable</td>
<td>Sedimentation with chemical coagulation, flocculation, and ballast.</td>
</tr>
<tr>
<td></td>
<td>✓ Colloidal</td>
<td></td>
</tr>
<tr>
<td><strong>Biologically Enhanced</strong> “A” Stage of A/B Process</td>
<td>✓ Particulate</td>
<td>Biosorption, bioflocculation, and sedimentation.</td>
</tr>
<tr>
<td></td>
<td>✓ Colloidal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ Soluble</td>
<td></td>
</tr>
<tr>
<td><strong>Biologically Enhanced</strong> Captivator*</td>
<td>✓ Particulate</td>
<td>Biosorption, bioflocculation, and flotation.</td>
</tr>
<tr>
<td></td>
<td>✓ Colloidal</td>
<td></td>
</tr>
<tr>
<td></td>
<td>✓ Soluble</td>
<td></td>
</tr>
</tbody>
</table>
Key Requirements of a Primary Filter

- Outside-In Pre-Screen
- Contending with Grease
- Built Like a Tank
- Capable of Handling Floatables
- Adjustable Media based on Site Needs
- Grit Handling Provisions
CSO Design Scenario

Excess Flow Bypasses Plant and Goes to Filtration Process Only
Ballasted Sedimentation
CoMag® Process Flow Diagram

- Clarifiers 80-90% smaller
  - Increase capacity up to 10X
  - Superior solids removal

- Optimize chemical use
- Promote solids-contact
Biological Enhanced Primary Treatment Captivator
Key Mechanisms: Biosorption & Bioflocculation

- **Total BOD Raw WW**
  - **True Soluble**
  - **Colloidal**
  - **Particulate**

- **Contact Tank: Short HRT and Mild Aeration**
  - Uptake
  - Coagulation
  - Enmeshment

- **Biological floc (WAS)**
  - Microorganisms
  - Biopolymers (EPS)

- **DAF: Flotation**
Why DAF?

Hydraulically efficient
• 5X smaller footprint than primary clarifiers
• Rapid transport of solids to digester

Thickener (coflotation)
• 4-6% solids without chemicals
• NO need for additional thickeners

Additional benefits
• Grit separation (settleable)
• FOG removal (floatable)
Knowledge Growth Timeline

1953
Katz Biosorption Study

1993
DAFT Coflotation, Renton, WA

1996-2010
Pilot Studies Bethlehem & Oconomowoc

2012-13
Pilot Study Singapore R&D Study

2014
Full-Scale Agua Nueva WRF (32 MGD)
Katz Study (1953)

Key Points:
- One of the first studies on biosorption mechanisms, tested sludge from four WWTP’s in WI
- Relationships were similar across the plants studied, and repeatable
- Evaluated contact time, with and without aeration (60 min w/ aeration)
- Developed isotherm to predict removal
- Sludge concentration plays a role
Renton, WA Plant Study (1993)

Key Points:

- 80% soluble BOD removal was observed, less returned in side streams versus gravity thickeners
- Co-flotation produces higher %TS conc.
- Grit removal in DAF [24,000 lb (10,900 kg) during two-day storm event]
- Digesters were “relatively free of accumulated grit”
Bethlehem, PA Pilot Study (1996)

Key Points:

- First Evoqua pilot
- Tested 5000 gpd/sf (8.5 m/hr) loading w/ 10-min contact tank
- Evaluated TSS & BOD removal with and without polymer (74% vs 66% TSS)
- 23-32% sBOD removal observed (colloidal & truly soluble)
- Co-flotation in primary DAF measured, with and without polymer (4-7%DS)
TSS removal results from bench scale study

“sBOD“ removal from Pilot
Oconomowoc, WI Pilot Study (2010)

Key Points:

- Testing conducted with Jacobs/CH2M in advance of Agua Nueva project
- Evaluated TSS & BOD removal with and without polymer & coagulant (73-90% TSS)
- Ability to achieve consistent float concentration at desired conc (2-3% DS)
- Peak flow testing conducted w/o chemical (69%)
Singapore R&D Pilot Study (2012-13)

Key Points:

- 37-gpm (200 cmd) micro plant constructed
- Baseline run and compared against two different modes of BEPT operation
- Complete mass balance performed
- 40-min contact tank
- Biogas production measured for first time (8.4 cmd vs 11 cmd → 31% increase)
**COD balance**

**CAS**

<table>
<thead>
<tr>
<th></th>
<th>CAS</th>
<th>Captivator System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxidized</td>
<td>39%</td>
<td>17%</td>
</tr>
<tr>
<td>Biogas</td>
<td>23%</td>
<td>38%</td>
</tr>
<tr>
<td>Final Effluent</td>
<td>6%</td>
<td>12%</td>
</tr>
<tr>
<td>Excess Sludge</td>
<td>32%</td>
<td>33%</td>
</tr>
</tbody>
</table>

**COD balance**

**Captivator System**
Agua Nueva WRF (2014)

Key Points:

- Award winning 32 MGD (121 MLD) facility in Tucson
- Scalping plant (no digesters)
- Combined grit removal, primary DAF, sludge thickening, and FOG removal in a single unit process
- 65% TSS & 25-30% sBOD removal
- Float consistently maintained ~2%
- Add supplemental carbon as needed
Agua Nueva – DAF TSS Removal

*Data Provided by CH2M (Includes estimated WAS TSS contribution to the influent)*
Agua Nueva – DAF sBOD Removal

*Data Provided by CH2M
We Learned...

- Aerated contact tank promotes biosorption & bioflocculation, need some HRT and good mixing
- Ability to handle peak flows, but need min A:S for effective removal
- Result is high functioning primary clarifier in small footprint
- Ability to reliably co-thicken w/o polymer in DAF
- Grit separation occurs
- FOG collection in float
- Supplemental carbon may be needed for Nutrients
Value Comparison

Primary Treatment (TSS & BOD removal)

Primary Treatment

Grit Separation

Primary Thickening

FOG Collection

WAS Thickening
<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>VALUE</th>
<th>UNITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contact time</td>
<td>10-40</td>
<td>minutes</td>
</tr>
<tr>
<td>DAF Air:Solids</td>
<td>ADF &gt; 0.03</td>
<td>mass basis</td>
</tr>
<tr>
<td></td>
<td>PDF &gt; 0.02</td>
<td></td>
</tr>
<tr>
<td>DAF Surface Overflow Rate (SOR)</td>
<td>ADF &lt; 5000 (8.5)</td>
<td>gpd/sf (m/hr)</td>
</tr>
<tr>
<td></td>
<td>PDF &lt; 10,000 (17)</td>
<td></td>
</tr>
<tr>
<td>DAF Solids Loading Rate (SLR)</td>
<td>ADF &lt; 20 (98)</td>
<td>ppd/sf (kg/m2-d)</td>
</tr>
<tr>
<td></td>
<td>PDF &lt; 30 (147)</td>
<td></td>
</tr>
<tr>
<td>Removal Efficiency (w/o chem) BOD5 TSS</td>
<td>50-55%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>65-75%</td>
<td></td>
</tr>
<tr>
<td>DAF Float (w/o polymer)</td>
<td>4-6%</td>
<td>dry solids</td>
</tr>
</tbody>
</table>
30 to 65% Biogas generation improvement over conventional PC
Captivator® Bench Testing

Contact Tank Simulation

DAF Simulation

Pressurized System
Captivator Demonstration Pilot Unit (0.3 MGD)
Captivator Pilot – BMP test

Higher PS:WAS ratio in float sludge to digestion
~12% more digestible sludge
System Impacts from Advanced Primary Treatment
<table>
<thead>
<tr>
<th>FEATURES</th>
<th>CHEMICALLY ENHANCED</th>
<th>MECHANICALLY ENHANCED</th>
<th>BALLAST ENHANCED SEDIMENTATION</th>
<th>BIOLOGICALLY ENHANCED (FLOTATION)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enhanced Carbon Diversion</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Compact Footprint</td>
<td>X</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Co-thickening w/o Chemical</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>Grit Separation</td>
<td>X</td>
<td>?</td>
<td>X</td>
<td>✓</td>
</tr>
<tr>
<td>FOG Capture</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>✓</td>
</tr>
</tbody>
</table>
When to Consider APT Process?

**Applications:**
- Plant Expansions
- Desire To Reduce Energy Demand
- Desire To Eliminate Thickening / Polymer (Captivator® Only)
- Plants Undergoing Biosolids / Energy Recovery Upgrades

**Good Candidates:**
- Have Digesters / Energy Recovery
- CEPT Facilities
- Converting From Fixed Film Or Pure Oxygen To Activated Sludge
- High Energy Costs (>0.08 KW/H)
- Grit Issues (Captivator® Only)
- FOG Issues (Captivator® Only)

©2018 Evoqua Water Technologies
References & Suggestions for Additional Reading


