Arkea®: A Green Technology for Wastewater Treatment, Residuals Management, and Pathogen Reduction

OWEA ANNUAL MEETING
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Michael H. Gerardi, Wastewater Biologist, ArchaeaSolutions, Inc.
Steve C. Owens, P.E., Vice President, ArchaeaSolutions, Inc.
I. Introduction
Science-focused company

Discovered how to use *Archaea* organisms to resolve environmental problems

Since 2000, *Archaea* containing bio-systems have worked in hundreds of municipal and industrial plants, including wastewater treatment, food processing, chemical plants, and petroleum refineries

Ongoing work in North America, Europe, and Africa
ArchaeaSolutions, Inc.

- Scientists, Engineers, and Wastewater Professionals Specializing in Plant Optimization, Troubleshooting, Process Consulting, and Bioaugmentation Strategies
- Usual approach is to evaluate problem and situation, perform lab analysis, complete pilot program, and undertake full scale work
II. What are Archaea

Archaea – Key Driver in Waste Stabilization
Archaea not bacteria

- Separate domain of life forms
- Characteristics of **Archaea** compared to bacteria
  - Larger diversity of enzymes
  - Higher metabolic rate
  - Shorter generation time
  - More tolerant of extremes
  - Larger surface-to-volume ratio
Archaea and bacteria: syntrophic relationship

Archaea degrade wastes that bacteria cannot degrade

Archaea solubilize wastes to substrates for bacteria

Less polluting wastes, non-polluting wastes, decreased sludge production
Additional benefits of syntrophic relationship

- Increase in numbers of higher life forms
  - Ciliated protozoa
  - Rotifers
  - Free-living nematodes
- Increase in coating action — removal of fine solids from bulk solution
- Increase in cropping action — removal of dispersed growth from bulk solution
III. Archaea Bioaugmentation

A. Waste Stabilization
B. Process Optimization
C. Pathogen Reduction
A. Waste Stabilization

- Solubilize colloidal and particulate cBOD and degrade solubilized cBOD to non-polluting wastes and less polluting wastes
- 1 lb. of non-soluble cBOD in and not solubilized is 1 lb. of solids out
- 1 lb. of non-soluble cBOD in and solubilized is 0.6 lb. of solids out under aerobic conditions

- RESULT: Reduction in solid management costs (Energy, Dewatering, Transportation, Disposal)
# Activated Sludge: Transformation of cBOD (Sludge Yield)

<table>
<thead>
<tr>
<th>Electron Acceptor</th>
<th>Sludge Yield per lb of cBOD degraded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen, $O_2$</td>
<td>~0.6</td>
</tr>
<tr>
<td>Nitrate, $NO_3^-$</td>
<td>~0.4</td>
</tr>
<tr>
<td>Sulfate, $SO_4^{2-}$</td>
<td>~0.04 - 0.1</td>
</tr>
<tr>
<td>cBOD, $CH_2O$</td>
<td>~0.04 - 0.1</td>
</tr>
</tbody>
</table>
Bacterial Growth (Sludge Production) Curve

- Increased MCRT
- Increasing Bacterial Population (MLVSS)
- Synthesis of cBOD
- Uptake of soluble cBOD
- LOG
- Endogenous/Basal
Activated Sludge/Microbial Wastes

- Non-polluting wastes
  - Water (H₂O)
  - Carbon dioxide (CO₂)

- Less polluting wastes
  - Ammonium (NH₄⁺)
  - Sulfate (SO₄²⁻)
  - Orthophosphate (H₂PO₄⁻/HPO₄²⁻)
  - Acids, alcohols, aldehydes, ketones including VFA, VNC, VSC
Nitrogen is removed by *Archaea* through anaerobic ammonia oxidation (ANAMMOX).

ANAMMOX is the oxidation of ammonium to nitrite ($\text{NO}_2^-$) and then the removal of molecular nitrogen ($\text{N}_2$) from nitrite to the atmosphere by combining nitrite and ammonium under an anaerobic condition.

ANAMMOX requires less dissolved oxygen and is not dependent upon carbon feed.
ANAMMOX reactions

\[
2\text{NH}_4^+ + 2\text{HCO}^- + 1.5\text{O}_2 \quad \longrightarrow \quad \text{NH}_4^+ + \text{NO}_2^- + 2\text{CO}_2 + 3\text{H}_2\text{O}
\]

Step 1

\[
\text{NH}_4^+ + \text{NO}_2^- \quad \longrightarrow \quad \text{N}_2 + 2\text{H}_2\text{O}
\]

Step 2
Key role in sulfur cycle

- Extremophilic Archaea domain are the source of strong sulfide-oxidizing bacterium such as Sulfolobus which break down hydrogen sulfide or its salts.
Control of malodors

- Compete with sulfate-reducing bacteria (SRB) for substrate
- Degrade VFA, VNC, VSC
- Release wastes that inhibit SRB
- Prevent conversion of HS\(^-\) to H\(_2\)S
  - Assimilate HS\(^-\) as sulfur nutrient
  - Oxidize HS\(^-\) to S\(^\circ\)
B. Process Optimization

- Increase number of cBOD-removing microbes without increasing MCRT
- Increase number of nitrifying microbes without increasing MCRT
Control of foam

- Foam
  - Biological
    - Degrade lipids
    - Degrade polysaccharides
  - Chemical
    - Degrade oils and grease
    - Degrade surfactants
Provide resistance to toxic wastes

- Degrade organic wastes such as phenol
- Safely bio-accumulate heavy metals
Heavy metal “attack” on microbial cell

- Fibril
- Cell Wall
- Cell Membrane
- Polysaccharide Coat
- Genetic Material
- Enzymes
- Zn$^{2+}$
Methane production

- Larger variety of methanogens
  - Larger variety of enzymes
  - Larger diversity of wastes that can be converted to methane (CH$_4$)
C. Reduction in *E. coli* and pathogens via *Archaea* augmentation

- Reduction in sludge age or mean cell residence time (MCRT)
- Competition for soluble nutrients and soluble substrate
- Adsorption to floc particles or biofilm
- Increase in cropping action by ciliated protozoa and metazoa
- Increase in coating action by ciliated protozoa and metazoa
- Reduction in chlorine demand
Competition for soluble nutrients and soluble substrates

- *E. coli* and some pathogens such as *Klebsiella* reproduce in wastewater!

- Because *Archaea* have a larger surface-to-volume ratio than *E. coli* and most pathogens, *Archaea* can out-compete *E. coli* and most pathogens for nutrients and substrates.

- Therefore, reduction in numbers of *E. coli* and some pathogens occurs!
Adsorption to floc particles or biofilm

- Archaea are adsorbed (flocculated) to floc particles or biofilm and remain for long sludge retention time (SRT) in the treatment process.

- Flocculation reduces the number of dispersed bacterial cells including E. coli and pathogens that are present in the secondary effluent!
Mature floc particle

Bulk solution has:
- Insignificant dispersed growth
- Insignificant particulate materials
Testate, free-swimming ciliates, *Coleps*
Because *Archaea* are able to reduce significantly the quantity of cBOD and nBOD (ammonia) in the secondary effluent, the chlorine demand for disinfection of *E. coli* and pathogens is reduced.

Therefore, the existing level of chlorine feed to the effluent is more effective.
IV. Arkea® Field Applications
ArchaeaSolutions, Inc. produces Arkea® substrate containing a proprietary blend of Archaea organisms and other selected microbes.

Several species of Archaeal methanogens have been identified in Arkea® through gene sequencing analysis.
- **Archaea** is the key driver
- Other supporting microbes and factors
  - Bacteria
  - Fungi
  - Nutrients/micronutrients
  - Job specific microbes
Ohio and Indiana Installations - Sludge Reduction and Operational Cost Savings
After the addition of Arkea® in 2009, the lbs. of WAS declined.

Sludge yield coefficient (lbs. WAS/lbs. BOD drop) also decreased.

<table>
<thead>
<tr>
<th>Year</th>
<th>WAS (lbs.)</th>
<th>Sludge Yield (lbs. WAS / lbs. BOD drop)</th>
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<tbody>
<tr>
<td>2008</td>
<td>15,806</td>
<td>1.07</td>
</tr>
<tr>
<td>2009</td>
<td>11,581</td>
<td>.95</td>
</tr>
<tr>
<td>2010</td>
<td>9,969</td>
<td>.80</td>
</tr>
</tbody>
</table>
Operational Impact - OH

- When OH project began, plant operated all four available sludge digesters.
- Due to impact of Arkea®, reduced operation to only two sludge digesters.
- Confirmation of reduced sludge yield.
Lagoon Biological Dredging - OH

Before: Note dark gray color

After: Note green color and improved appearance
TSS and VSS Reductions - OH

**TSS**

<table>
<thead>
<tr>
<th>Date</th>
<th>%TSS</th>
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<tbody>
<tr>
<td>6/2/2010</td>
<td>3</td>
</tr>
<tr>
<td>7/21/2010</td>
<td>2.5</td>
</tr>
<tr>
<td>9/22/2010</td>
<td>2</td>
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</table>

**VSS**

<table>
<thead>
<tr>
<th>Date</th>
<th>%VSS</th>
</tr>
</thead>
<tbody>
<tr>
<td>6/2/2010</td>
<td>62</td>
</tr>
<tr>
<td>7/21/2010</td>
<td>56</td>
</tr>
<tr>
<td>9/22/2010</td>
<td>52</td>
</tr>
</tbody>
</table>
Municipality with a 24/7 slaughterhouse upstream could not cost effectively manage their bio-solids.

Dark brown area is >100”. Orange is 80 – 100”. Gold is 60 – 80”. Dark yellow is 40 – 60”. Yellow is 20 – 40”. Vanilla is <20”.

Fraction of cost of mechanical dredging.
Hydraulic Volume Increase - Texas Lagoon
NH3 Compared to 001 Outfall Limits

- Monthly Avg
- Daily Max
- 001 Monthly Avg Limit
- 001 Daily Max Limit
Nitrate Reduction
Explosives Manufacturer - AR

NO₃ Compared to 001 Outfall Limits

- Monthly Avg
- Daily Max
- 001 Monthly Avg Limit
- 001 Daily Max Limit
Poultry Processing WWT Lagoon - GA
Total Nitrogen and Total Phosphorus Reduction

Before Arkea® Treatment

After Arkea® Treatment
Poultry Processing
Total Nitrogen - GA

Total Nitrogen: > 50% reduction
Poultry Processing
Total Phosphorus - GA

Total Phosphorus: > 50% reduction
Phosphorus Field Results - FL

- Phosphorous reduction on dairy farms in central Florida
- Normally the dairy lagoons would be filled with bio-solids and often have a bio-solid crust on top.
Sweden Refinery - Acid Tar By-Product Reduction, Detoxification, and Re-Use
Ammonia Reduction -
London 2012 Olympic Stadium
Bioresmediation - Underground Petro Storage Tank - BTEX Reduction
V. Summary
Process Benefits of **Arkea®** Bioaugmentation

- More rapid degradation of wastes
- Reduction of waste by-products
- Reduction of sludge yield
- Reduction in concentrations of ammonia, nitrate, phosphorus, TKN, H$_2$S, and sulfides
- Reduction in toxicity
- Overall improvement of effluent water quality

**Arkea®** are proven safe in the environment.
Operational Cost Savings

- **Arkea®** substrate improves operating profit.

- The operational cost savings will come from the following areas:
  - Typically 25-50% reduction in sludge yield
  - Reduced sludge handling and disposal costs
  - Decreased energy costs
  - Decreased chemical usage
  - Improved overall plant efficiency and operation

- **Arkea®** substrate does all this in a **cost effective** manner
Scientists, Engineers, and Wastewater Professionals
Specializing in Plant Optimization, Troubleshooting,
Process Consulting, and Bioaugmentation Strategies

100 Lloyd Ave., Suite D, Tyrone, GA 30290
770-487-5303
www.archaeasolutions.com

Low Cost “Performance-Based” Arkea® Trials Available
Call us today to schedule a consultation and site visit!