“Onsite Wastewater Treatment Experts since 1991”
Improving Septic Tank Performance by Enhancing Anaerobic Digestion

AOWMA

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A Legacy in Research

Craig Jowett, Ph.D., P.Eng., founder of Waterloo Biofilter

The patented Waterloo Biofilter was developed at the University of Waterloo, in the Waterloo Centre for Groundwater Research.
History

1991 - First Pilot Plant
1995 – Waterloo Biofilter was Incorporated

Developed in Canadian cold-climate

What we do, Departments in the company – service and maintenance, engineering, R&D, production
Waterloo’s BNQ Testing

Waterloo tested in 2014–2015 at BNQ’s facility outside Quebec City

During the coldest winter on record!

Waterloo passed the highest quality test – Level IV (BNQ B-IV) at 10°C
Outline

• Anaerobic 101
• Important factors influencing treatment
• Opportunity to improve septic tank performance
• Improving anaerobic digestion in septic tanks
Anaerobic 101
Anaerobic Processes

• We enjoy the products of anaerobic processes every day
• Anaerobic processes are used commercially in:
  • Food & Beverage
  • Pharmaceuticals
  • Bio-energy (Ethanol & Biogas)
  • Bioremediation
  • Wastewater treatment (obviously...)
Rationale for Anaerobic Processes

Advantages
- Low energy use
- Energy recovery
- Less sludge
- Lower nutrient requirements
- High organic loading rates = small reactors
- Viable for intermittent use

Disadvantages
- Slow growth of methanogens = biomass retention is critical (long start-up times)
- Odours
- Alkalinity
- Cannot achieve low effluent BOD
**How do we know it’s “anaerobic”?**

*ORP = oxidation / reduction potential*

<table>
<thead>
<tr>
<th>Process</th>
<th>ORP, mV</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aerobic</strong></td>
<td></td>
</tr>
<tr>
<td>Oxidation (O₂)</td>
<td>+100 or higher</td>
</tr>
<tr>
<td><strong>Anoxic</strong></td>
<td></td>
</tr>
<tr>
<td>Denitrification (NO₃⁻)</td>
<td>-100 to +100</td>
</tr>
<tr>
<td><strong>Anaerobic</strong></td>
<td></td>
</tr>
<tr>
<td>Sulphide production</td>
<td>-50 or less</td>
</tr>
<tr>
<td>Fermentation, Bio-P release</td>
<td>-100 to -225</td>
</tr>
<tr>
<td>Methanogenesis</td>
<td>-175 or less</td>
</tr>
</tbody>
</table>

ORP = oxidation / reduction potential
Anaerobic is Like a Family

- Many different biomass groups working together (syntrophy)
- Different growth rates: fermentation (fast) vs methanogenesis (slow)
  - "Stuck" digesters
  - Need to balance give & take
  - Understand rate limiting step
- Granular sludge: the close knit family
Factors Influencing Anaerobic Treatment
**Organic Loading Rate (OLR)**

- OLR = kg COD fed per day per m\(^3\) reactor volume
- Typical OLR:
  - Aerobic: 0.5 to 3.2 kg/m\(^3\)/d
  - Anaerobic: 3.2 to 32 kg/m\(^3\)/d

- Factors:
  - Biomass conc. (SRT)
  - Reactor configuration
  - Substrate mass transfer
  - Temperature, pH & toxicity
  - Type of wastewater
**Reactor Configuration**

• **Plug flow reactors** are critical for efficient anaerobic treatment
  • Much improved growth kinetics
  • Eliminate short-circuiting
  • Smaller reactor

• **Biomass retention** is critical:
  • Maintain high biomass inventory
  • Separate SRT from HRT
  • Depends on granulation
Biomass Retention is Critical

- Long SRTs required = critical need to retain biomass in the reactor
- Many different reactors developed and used for anaerobic treatment:

**Low-Rate**
- Unmixed sludge digester
- Covered lagoon
- Standard septic tank

**High-Rate**
- Anaerobic filter (AF)
- Up-flow Anaerobic Sludge Blanket (UASB)
- Expanded Granular Sludge Blanket (EGSB)
- Anaerobic Baffled Reactor (ABR)
Factors in Septic Tanks

- Biological treatment can be improved by:
  - **Higher temperatures**; more active and different types of bacteria available: Psychrophyllic (15 - 25°C) → Mesophyllic (35 - 40°C) → Thermophyllic (50 - 60°C)
  - **Longer retention time**; more time for bacteria to work on sewage
  - **More anaerobic environment**; better conditions for dense bacterial growth
  - **Reduced turbulence** and **reduced short-circuiting**
  - **Longer settling distance**; can remove smaller TSS particles
  - **Flow through sludge**; brings water to bacteria and removes toxic waste products
Why A Better Septic Tank Is Needed
Louis Mouras 1860 (France)

• Original Mouras Tank
  • Solids collection/contact chamber
  • Even after 10 years observed that few solids remained

• Modified Mouras Tank
  • Vent connections
  • No airspace
  • Flow path tends to cause flow through sludge
“Modern” Septic Tanks

• Not very modern...basically the same as 150 years ago!
• Highly prescriptive design enshrined in local regulations
• Designed & operated as a primary clarifier:
  • Settle sludge, float FOG
• Use effluent filter to keep solids in the tank
• Little consideration as a biological treatment technology (except to assume low-rate sludge digestion)
Septic Tanks: Problems & Opportunities

• Non-ideal hydraulics:
  • Short-circuiting
  • Dead space
  • Turbulence at orifices
  • Poor treatment in tank corners & in sludge
Septic Tanks: Problems & Opportunities

- Scum layer
  - Becomes hard and solid
  - More difficult to pump and inspect
  - Takes up space
  - Lack of contact with biomass for degradation

- Scum can be minimized
  - Modified Mouras tank (1881) didn’t have an airspace
  - Recent work confirms
Septic Tanks: Problems & Opportunities

• Sludge layer:
  • No contact with soluble pollutants
  • “Low-rate” system

• Sludge can be minimized
  • Increased SRT
  • Flow through sludge
  • “High-rate” system
  • Recent work confirms
Septic Tanks: Problems & Opportunities

• Opportunity: improve design to increase biological treatment
• Apply 30 years of innovation in high-rate anaerobic treatment:
  • WaterTube™ septic tank
  • Anaerobic Digester Pretreatment Tank using InnerTube™
Improving Anaerobic Digestion in Septic Tanks
WaterTube Septic Tank

- Long, narrow flow path reduces turbulence; increases retention time
- No airspace in ‘flooded’ tank creates highly anaerobic environment; reduces scum formation
- Flow through sludge areas increases digestion; reduces sludge formation
- Short-circuiting not possible
- Longer settling distance

- Improves cBOD by 6% - 23%
- Improves TSS by 18% - 30%
- Produces less than half the sludge
Accelerated field testing using sewage at Buzzards Bay test facility, MA

- sludge & scum accumulation
- effluent composition
- compare with standard tank
WaterTube Septic Tank

Sludge & scum measurements

Conventional tank has heavier scum & sludge

WaterTube tank has 50% less solids; scum only at inlet
WaterTube Septic Tank

Inlet has scum

Outlet has no scum

Middle of tank has no scum; little ‘digested-looking’ sludge

Outlet has no scum; little sludge
Septic Tank Sludge Production

Sludge & scum in conventional design tank >33% solids within 3 months

June 28, 2005
August 22, 2005
September 29, 2005
November 29, 2005
WaterTube Sludge Production

Sludge & scum in WaterTube; scum doesn’t form where no sludge exists below
WaterTube Overview

- Improved treatment; almost no scum
- Less than half the sludge
- Less than half the pump-outs
- Larger footprint
- Higher costs
  - More material per volume retained

Can we replicate the WaterTube’s improved treatment & reduced sludge in a smaller, less costly manner?
Anaerobic Digester
Anaerobic Digester

- Simple modification to a standard septic tank
Anaerobic Digester Testing

- MASSTC Cape Cod – 1293 days of testing
- Plastic tank with InnerTube pipe
- Average cBOD = 101 mg/L (47% removal)
- Average TSS = 51 mg/L (75% removal)
Anaerobic Digester Testing

- Day 1293 after 3.5 years of continuous daily dosing:
  - Scum only at inlet end
  - No scum at outlet end
  - Loose sludge in InnerTube
  - 6” of loose sludge at outlet end
Anaerobic Digester Testing

- Ontario Septic Tank vs. Anaerobic Digester

- Septic tank inlet day 239
  - Solids so thick they support a metal rod
  - Sludge entire depth of tank
  - Tank required pump-out

- Digester inlet day 239
  - Scum free outside InnerTube
  - Little sludge in tank
  - Tank not pumped-out and testing continued
Anaerobic Digester Testing

- Septic tank Day 540 (301 days since pump-out)
  - Inlet has 22” of sludge (45% volume)
  - Pump-out required by law again

- Digester Day 540 (never pumped-out)
  - Still no scum
  - Inlet has 13” of sludge
  - No pump-out
Performance Factors in Septic Tanks

- Anaerobic Digester provides:
  - Higher temperatures
  - Longer retention time (SRT & HRT)
  - More severe anaerobic environment (‘no airspace’)
  - Reduced turbulence and reduced short-circuiting
  - Longer settling distance
  - Flow through sludge provides efficient contact between biomass and substrates; removes waste products
Anaerobic Digester Process

- Process similar to ‘Upflow Anaerobic Sludge Blanket’ (?)
  - Raw sewage enters bottom
  - Flows upwards through blanket of granulated sludge
  - Filtered and treated by sludge

- Process is being further looked into with some microscope and microbiology work...
Anaerobic Digester Maintenance

- Scum is often most difficult part to pump
- Scum and sludge in anaerobic digester are soft and move easily
- Pumping out a pipe is easy – high scouring
- No 4” inlet tee & no effluent filter – less chance of blockages
Anaerobic Digester Overview

• Improved treatment; almost no scum
• Less than half the sludge
• Less than half the pump-outs
• Same footprint
• Marginal cost increase
  • Pipe inside a septic tank
The Waterloo Advantage

• Highlights the main benefits:
  • Designed for difficult sites
  • Thoroughly tested
  • Permanent filter media
  • Low energy & maintenance
  • Small footprint
  • Designed for Canadian climate
Products

- Links to detailed descriptions of various residential products

Waterloo has multiple product configurations to meet your needs.

Residential Biofilters

- Basket Biofilters
- HDPE Tank Biofilters
- Flat Bed Biofilters
- Cedar Shed Biofilters

Find an Installer
Nitrogen Removal

Options:

1. Single-Pass Waterloo System
   • 25 – 35% TN removal
   • Internal carbon source of wastewater

2. Double-Pass Waterloo System
   • 50 – 65% TN removal
   • Septic tank carbon source through recirculation

3. WaterNOx-LS Autotrophic Upflow System
   • 80 – 95% TN removal
   • Passive agricultural sulphur source to Biofilter effluent
Waterloo EC-P – Replaceable Electrodes
Waterloo EC-P Finalist for Prestigious Prize

- Waterloo EC-P technology selected as top 15 Finalist in Stage 1!

The Waterloo EC-P system mimics soil processes to mineralize phosphorus as crystalline vivianite before entering groundwater, and can recover and re-use sewage P as a fertilizing soil amendment.
Thank you for your attention!