National Research Council of Canada

Ottawa, ON & Montreal, QC
(Canada's premier science and technology research organization)

Fairbanks, AK
(Researchers and developers of sewage treatment equipment for the Arctic)

Preliminary Test Results from an Electrically-Assisted, Anaerobic Sewage Treatment System

Subtitle:

Bio-Electrochemical Anaerobic Sewage Treatment (BEAST) technology for energy-efficient wastewater treatment in northern communities

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1 – Lifewater Engineering Company
2 – National Research Council of Canada

Topics covered

BEAST technology by NRCC

Pilot test by Lifewater

Brief History

Background

- NRCC developing anaerobic treatment technology
- Lifewater Engineering Company building aerobic STP's for cold climates since 1999

Events

- Late 2015 NRCC personnel visited Lifewater
- Established collaborative research agreement
- Lifewater built full-size residential anaerobic STP
- WIHAH

Objective: Sustainable wastewater treatment

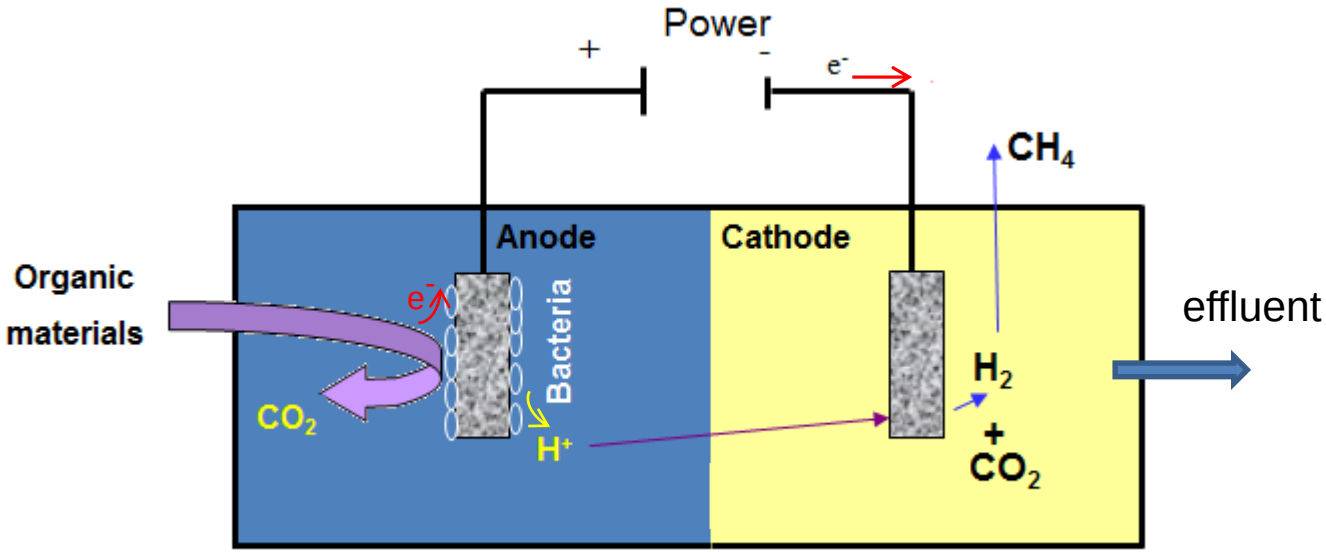
- Simple and robust (extreme conditions), relying solely on local staff for operation and management
- Meet or exceed effluent quality standards (BOD_5≤25 mg/L; SS ≤25 mg/L)
- Energy-efficient
- Low upfront investment and low operating costs

Microbial Electrochemical Technology

Concept: a low voltage (0.5 - 1.5 V) is applied to enable electron transfer (enhance biodegradation)

Anode reaction (bacteria): Organic materials + water $\rightarrow$ CO_2 + n e^- + n H^+

Cathode reactions: $8H^+ + 8e^- \rightarrow 4H_2$; $CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$



- H_2 is readily transformed to methane by methanogens

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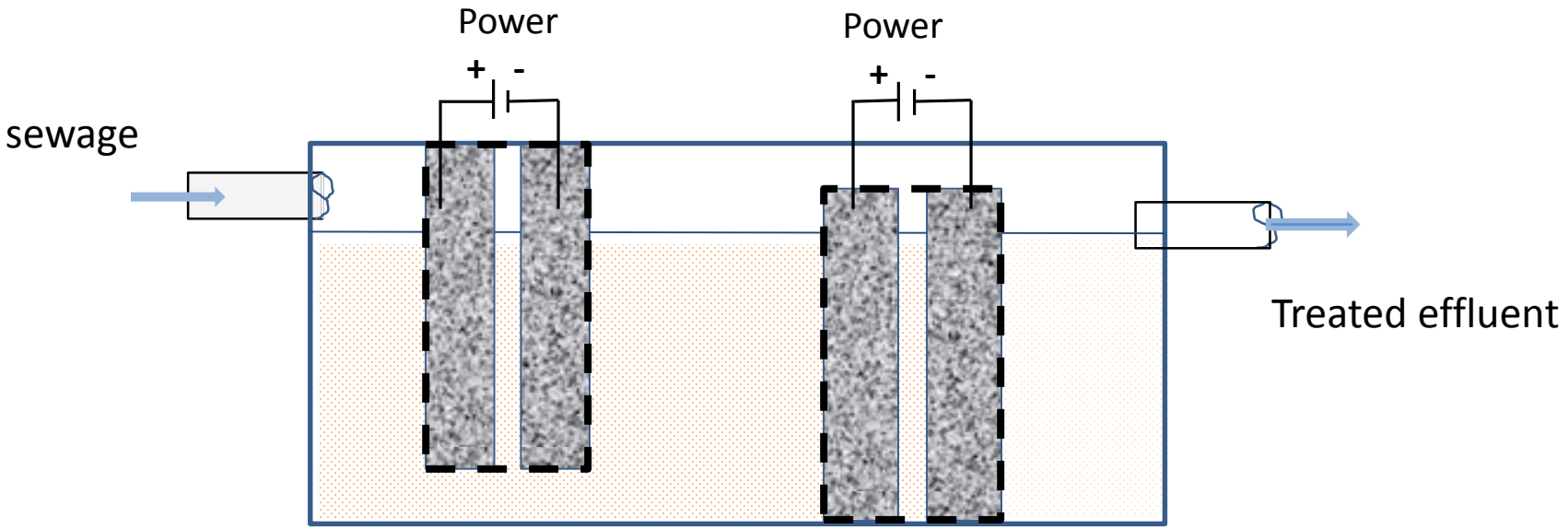
Bioelectrochemical Anaerobic Sewage Treatment (BEAST) technology



- Reactor design similar to septic tank (simple)
- Porous conductive electrodes
- Low voltage power supply used to enhance anaerobic degradation of sewage

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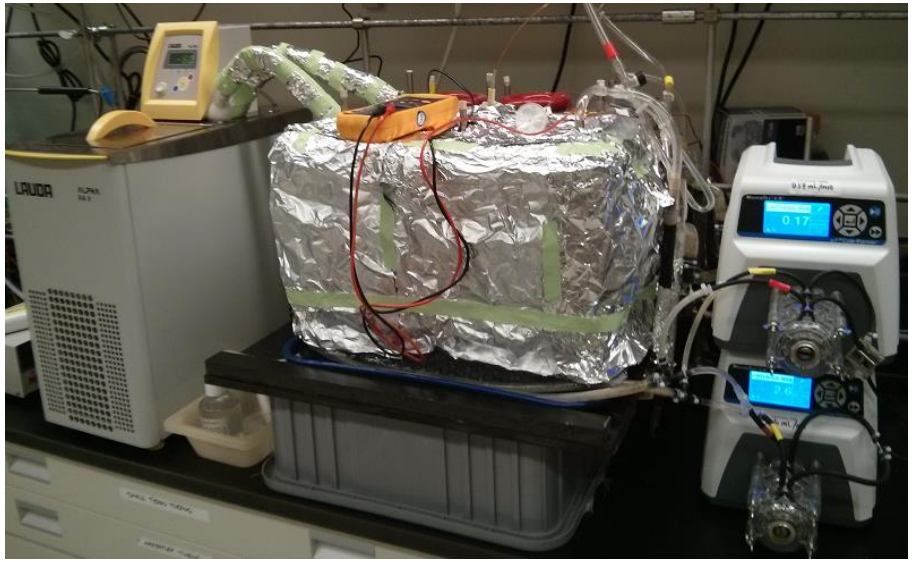
Laboratory setup in Montreal, QC

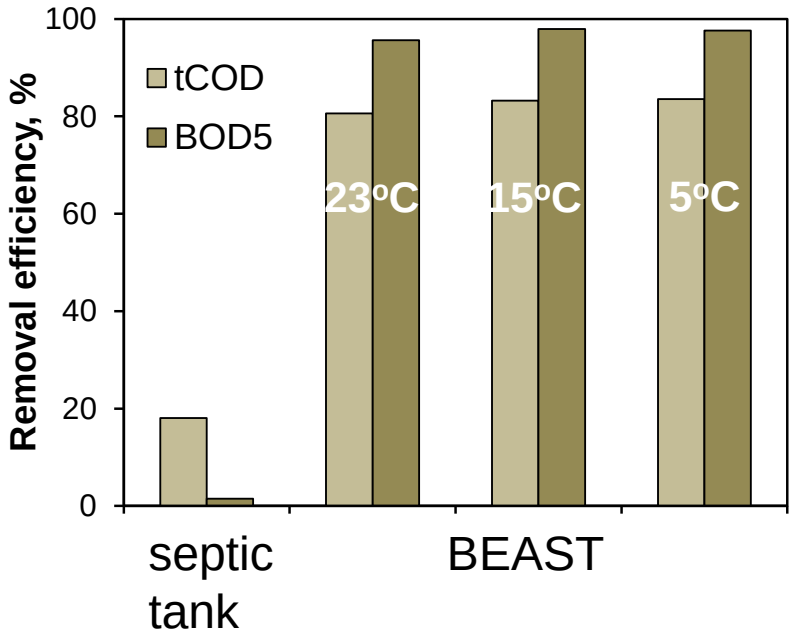


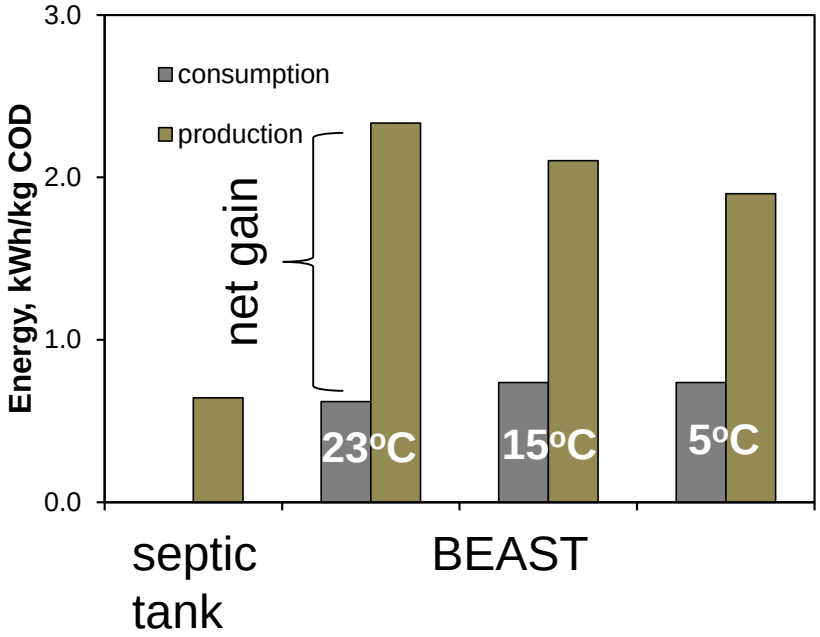
Operating conditions

- Hydraulic retention time 3.3 days
- Continuous flow
- Tests at 22°C, 15°C, and 5°C
- Applied voltage: 1.4 V

- 20 L reactor
- Synthetic and municipal sewage
- Tests at different temperatures

COD/BOD_5 removal and energy balance





BEAST performance:

- Influent BOD_5 : 350 mg/L
- Effluent BOD_5 : 7-15 mg/L (96-97% removal)
- Suspended solids: 20-40 mg/L
- Colony forming units (CFU): two log reduction

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Pilot test at MWWTP (Ste Catherine, QC)

- Test period: April to August, 2016
- 50 L reactor (40 L fluid volume)
- Raw sewage characterization (after primary grit removal):

  Total COD: 500 - 530 mg/L
  BOD_5 : 230-250 mg/L
  Suspended solids: 300-330 mg/L
- Single pair of electrodes (anode & cathode)
- Inflow rate varied to examine performance at different HRTs (17, 3.1, 2.8, 1.3 and 1.6 days)
- tCOD, sCOD, BOD_5, TSS and fecal coliforms monitored

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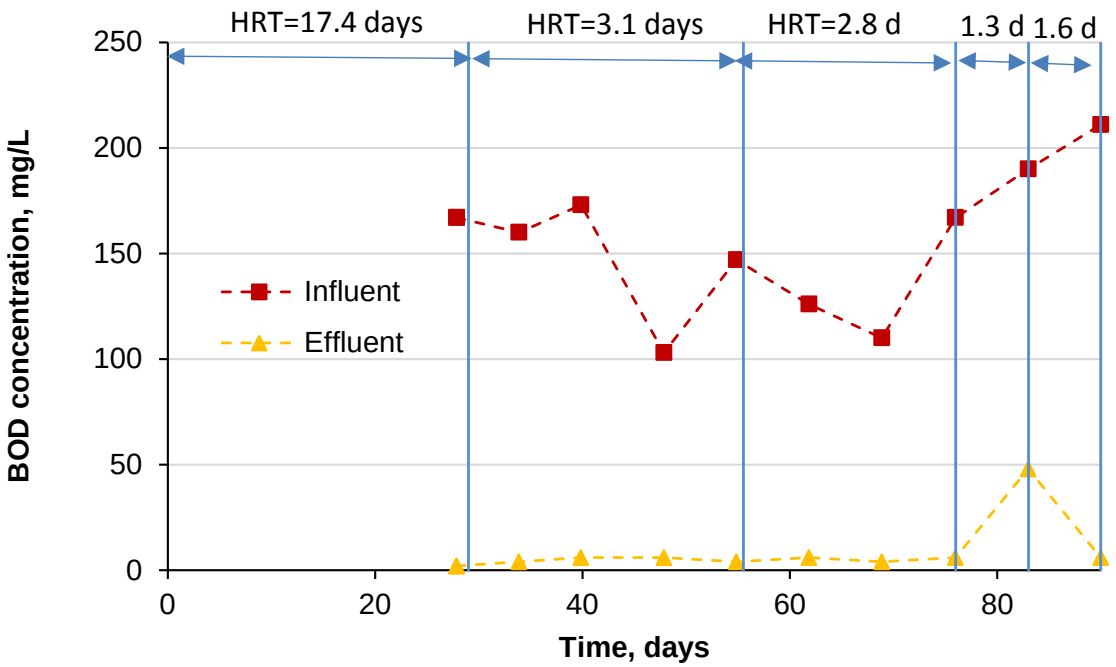
Pilot test - BOD_5 removal



HRT (days)	Mean Influent	Mean Effluent	% removal
17.4	167	2.0	98.8%
3.1	145	5.3	96.3%
2.8	137	5.0	96.4%
1.3	190	48.0	74.7%
1.6	211	6.0	97.2%

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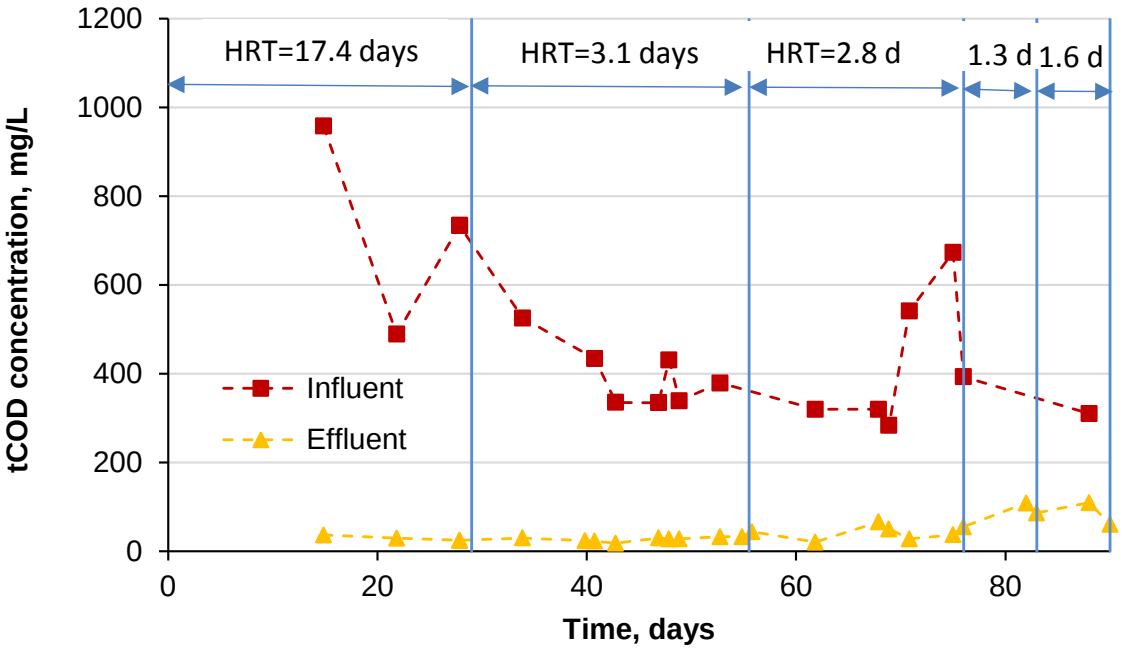
Pilot test – total COD removal



HRT (days)	Mean Influent	Mean Effluent	% removal
17.4	729	29.1	96.0%
3.1	397	26.9	93.2%
2.8	428	40.6	90.5%
1.3	428	97.8	77.1%
1.6	463	85.3	81.6%

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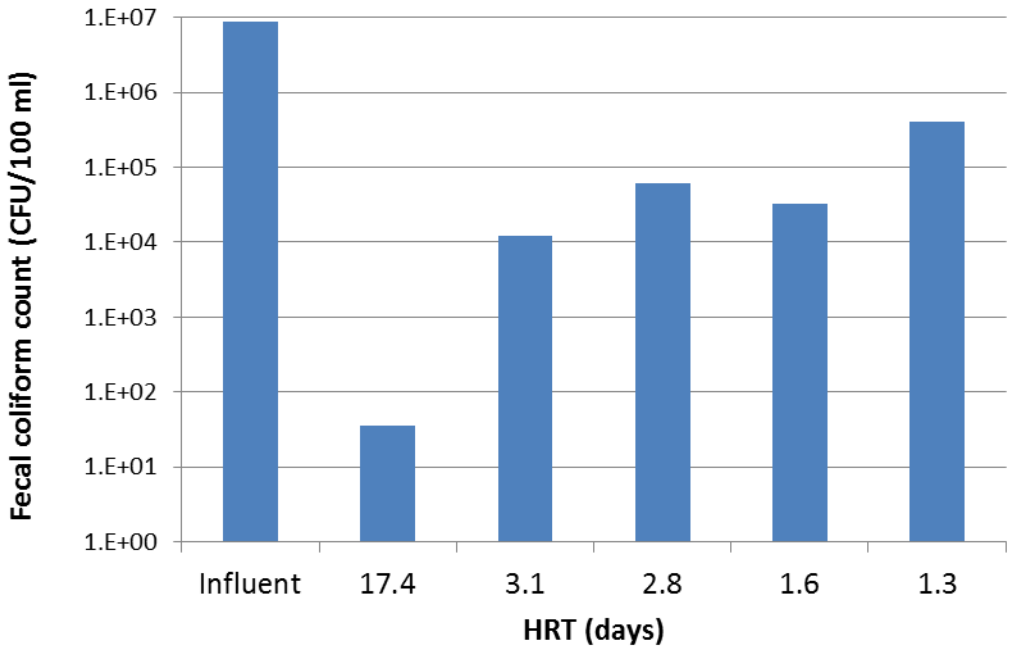
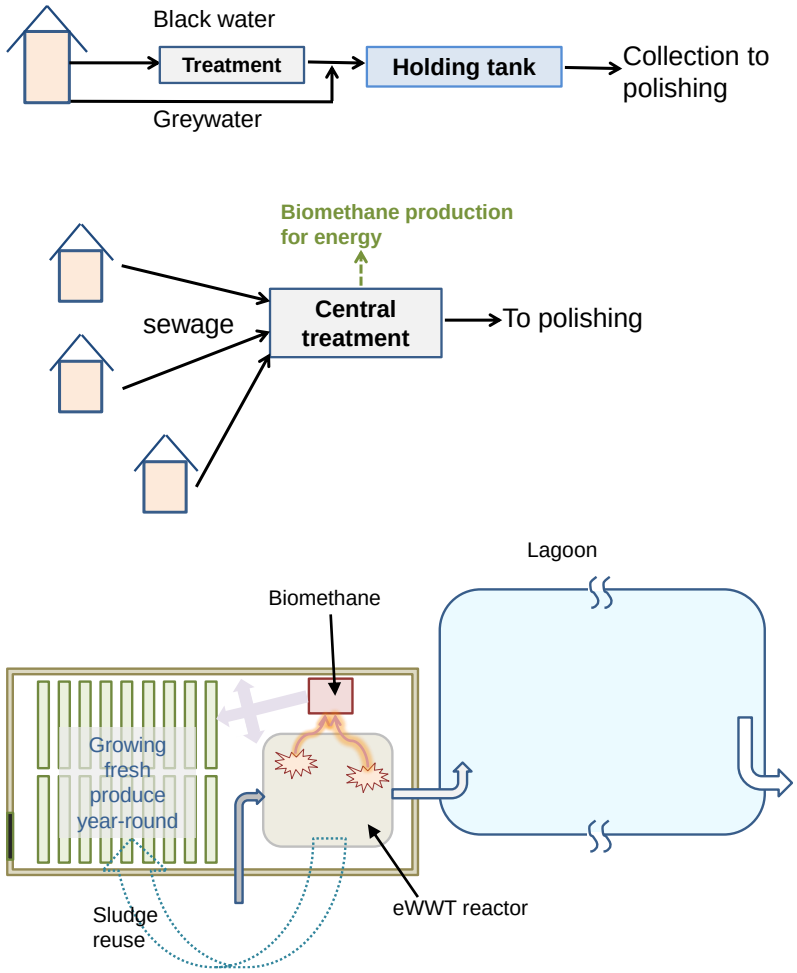
Pilot test - fecal coliform removal



- Two log reduction in fecal coliforms (before disinfection)

NRCC Conclusions

- Electrically assisted anaerobic wastewater treatment demonstrated high effluent quality (likely to exceed standards)
- Proven net energy gain (if bio-methane can be used)
- Simple design (could be used in conjunction with lagoon treatment)
- Fully scalable (from single-dwelling unit to community level)



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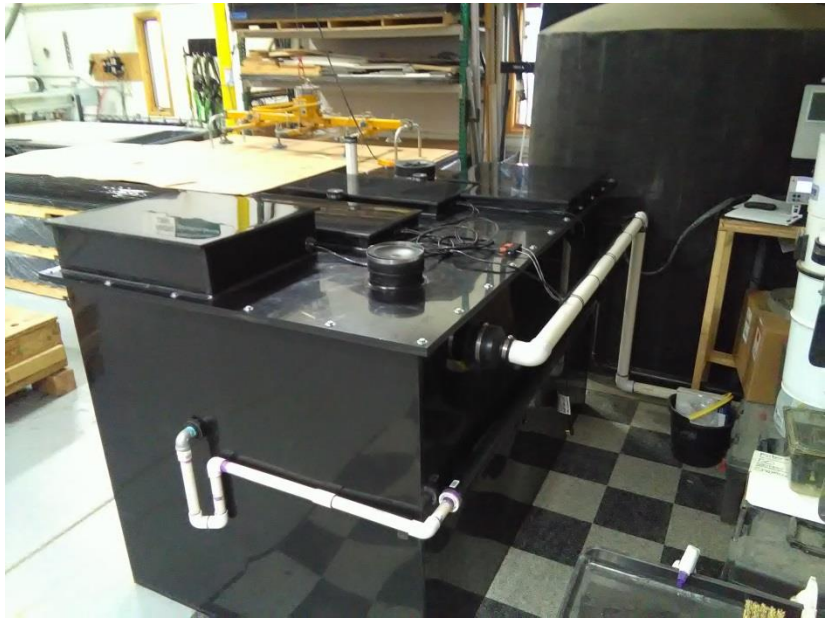
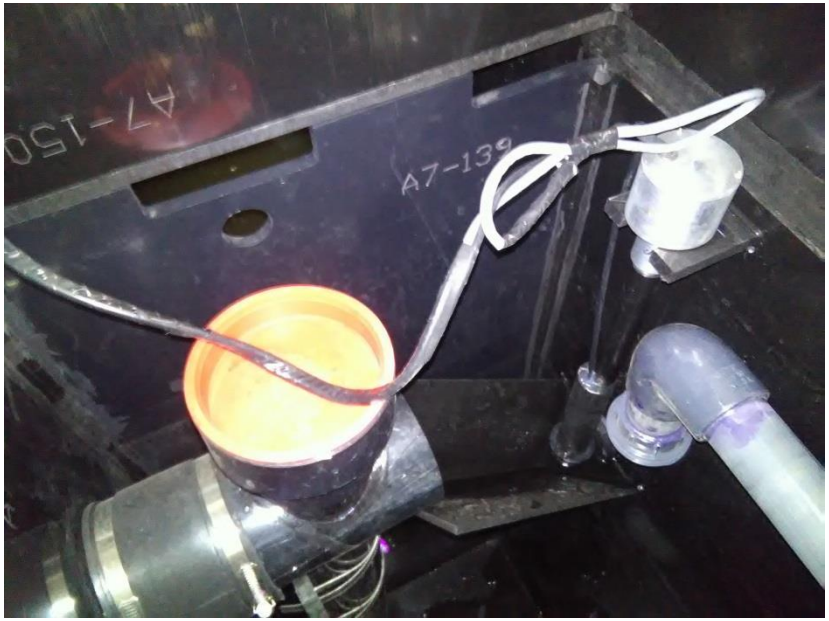
Residential full-scale system at Lifewater (Fairbanks)

~2800L



~7 days retention time

Programmable power supply & COD fluorimeter



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Sources of domestic sewage

- 3-bedroom upstairs apartment
- Office with 2 to 3 people
- Shop with 3 to 6 people
- Occasional visitors

Timeline

- Began filling system with sewage – Sept. 2nd
- System mostly full; turned on power – Sept. 9th
- Got COD fluorimeter operating – Sept. 13th
- First influent and effluent COD samples to the laboratory – Sept. 14th
- Now Sept. 19th – just 10 days after power was turned on

Effluent results five days after startup

- Influent COD: 357 mg/L (after primary treatment)
- Effluent COD: 147 mg/L (59% removal)

(expect 4 to 6 weeks of operation to achieve a steady state)

Power comparison five days after startup

Aerobic STP

	kWh/day
• Air blower	1.10
• UV	0.96
• Effluent pump	0.08
• Heat trace (50F inside)	4.51

BEAST

	kWh/day
• Electrodes	0.05
• UV (add float control?)	0.96
• Effluent pump	0.08
• Heat trace (35F inside)	less (add insulation, use methane)

Assuming all goes well with effluent quality, what happens next?

- Simplify treatment system as much as possible
- Reduce power use
- Optimize design for fabrication
- Apply arctic engineering
- Fabricate welded plastic tank (insulated, double-walled)

Welded plastic tanks

- Lightweight
- Never corrodes
- UV resistant
- Extremely durable!

Test in rural Alaska

- Test at one or more homes in rural Alaska

Challenges ahead (on a residential scale)

- How best to capture and contain the methane
- A simple, safe method to use the methane to:
  - Keep the system warm
  - Generate power for the electrodes
  - Some other purpose

Please share your ideas, experiences, and needs with us

God bless you in your endeavors to advance
healthy Arctic living around the world!